

October 1960

75¢

# SEMICONDUCTOR PRODUCTS

PARAMETRIC MODE TRANSISTOR



Transistor Switching Analysis  
Measurements in Monocrystals  
Transistor Choppers





TO-18 Case

For unprecedented efficiency  
at low signal levels  
plus extreme  
temperature stability...

## HOFFMAN NOW OFFERS YOU SILICON UNI-TUNNEL\* DIODES

These unique devices, sometimes referred to as "backward" diodes, utilize the tunneling effect to achieve high forward conductance at very low voltage levels. When they are biased in the reverse direction, the familiar tunnel diode current characteristic appears as a leakage current measurable in microamperes.

### TYPICAL APPLICATIONS

Ability of the Uni-Tunnel diode to operate efficiently at low voltage levels eliminates the complex circuitry previously required for low-level operations, resulting in lower cost, greater reliability and decreased space requirements (see modulator circuit at left). Benefits like these also make Hoffman Uni-Tunnel diodes ideal in:

- computer logic
- detectors    ■ choppers    ■ clamped
- tunnel diode circuitry

### SPECIFICATIONS

Twelve types available with minimum forward currents as high as 10 mA (at 0.25V) and maximum reverse currents as low as 5.0  $\mu$ A (at 0 to 0.5V). Operating and storage temperature range is -85°C to +200°C.

### STANDARD AND CUSTOM-ENGINEERED UNITS AVAILABLE IMMEDIATELY IN QUANTITY

Contact factory, El Monte, California, or your local Hoffman sales office for further information. Ask for Technical Data Sheet 131-760 UTD.

# Hoffman

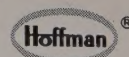
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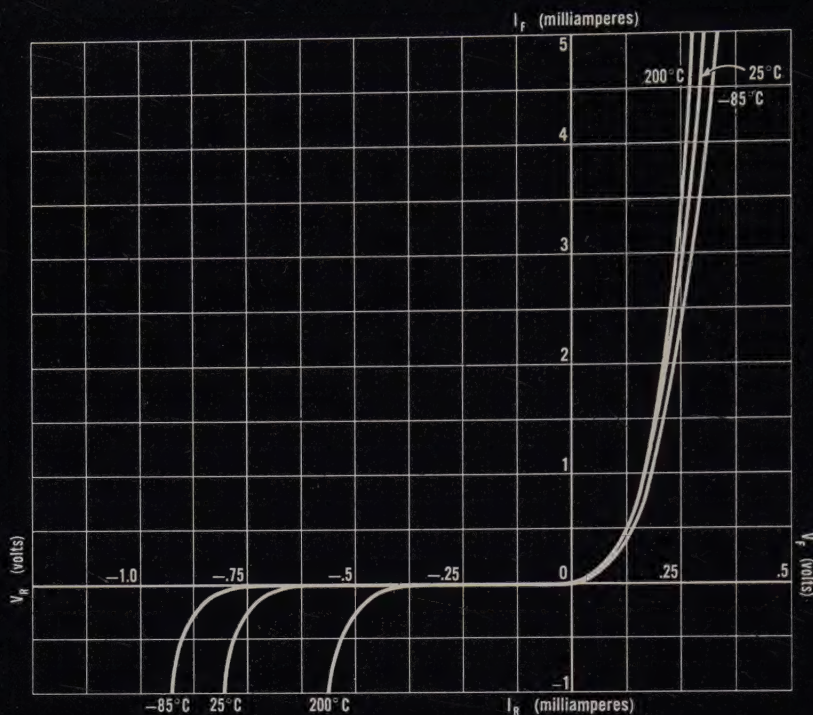
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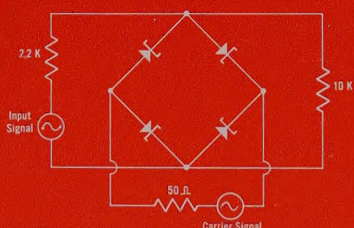


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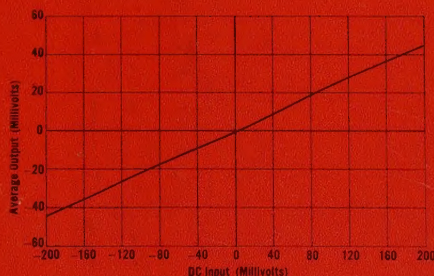
TYPICAL UNI-TUNNEL DIODE CHARACTERISTICS

### HOW HOFFMAN UNI-TUNNEL DIODES SIMPLIFY AND IMPROVE MODULATOR CIRCUITRY DESIGN

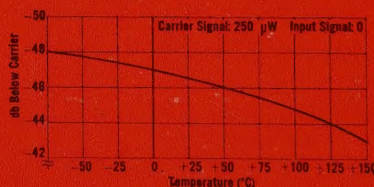


BRIDGE MODULATOR CIRCUIT UTILIZING FOUR  
HOFFMAN UNI-TUNNEL DIODES

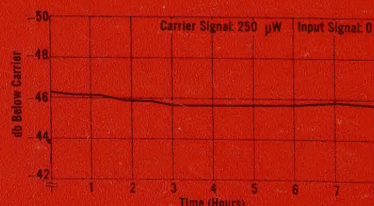
These Graphs Illustrate Typical Operating Characteristics of the Modulator Circuit Above



MODULATOR LINEARITY  
Average Output Voltage Versus DC Input Voltage



DRIFT VERSUS TEMPERATURE  
Change of Output Power (db) Versus Temperature



DRIFT VERSUS TIME  
Change of Output Power (db) Versus Time (25°C)

Write for details in Hoffman Application Notes - Volume II, Number 1



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# SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

October 1960

Vol. 3 No. 10

## CONTENTS

|   |    |
|---|----|
| Editorial .....   | 27 |
| Transistor Choppers, by J. A. Ekiss .....   | 27 |
| Resistivity, Crystal Perfection, and Lifetime Measurements in Silicon and Germanium Monocrystals, by Dr. A. S. Tulk ..... | 27 |
| Introduction to Semiconductor Theory and Reverse Breakdown (Part III), by C. A. Escoffery, Ph.D. ....                     | 36 |
| Transistor Switching Analysis (Part III), by Dr. C. A. Mead .....   | 38 |
| Applications Engineering Digests .....  | 43 |
| Semiconductor and Solid State Bibliography .....  | 44 |
| Patent Review .....   | 47 |
| Characteristics Charts of New Diodes and Rectifiers .....   | 49 |
| Departments   |    |
| Industry News .....   | 54 |
| Market News .....   | 55 |
| New Products .....  | 56 |
| New Literature .....  | 64 |
| Advertisers' Index .....  | 66 |

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### Front Cover

Parametric mode transistor operating at ultra-high and microwave frequency ranges has been developed by Hughes Aircraft Company's semiconductor division for operation in circuits invented by Lenkurt Electric Co., Inc., a subsidiary of General Telephone & Electronics. Pointer indicates transistor mounted in circuit, both in development stages. Inventors believe both will lead to circuit simplification in communications equipment and possibly in electronic computers.

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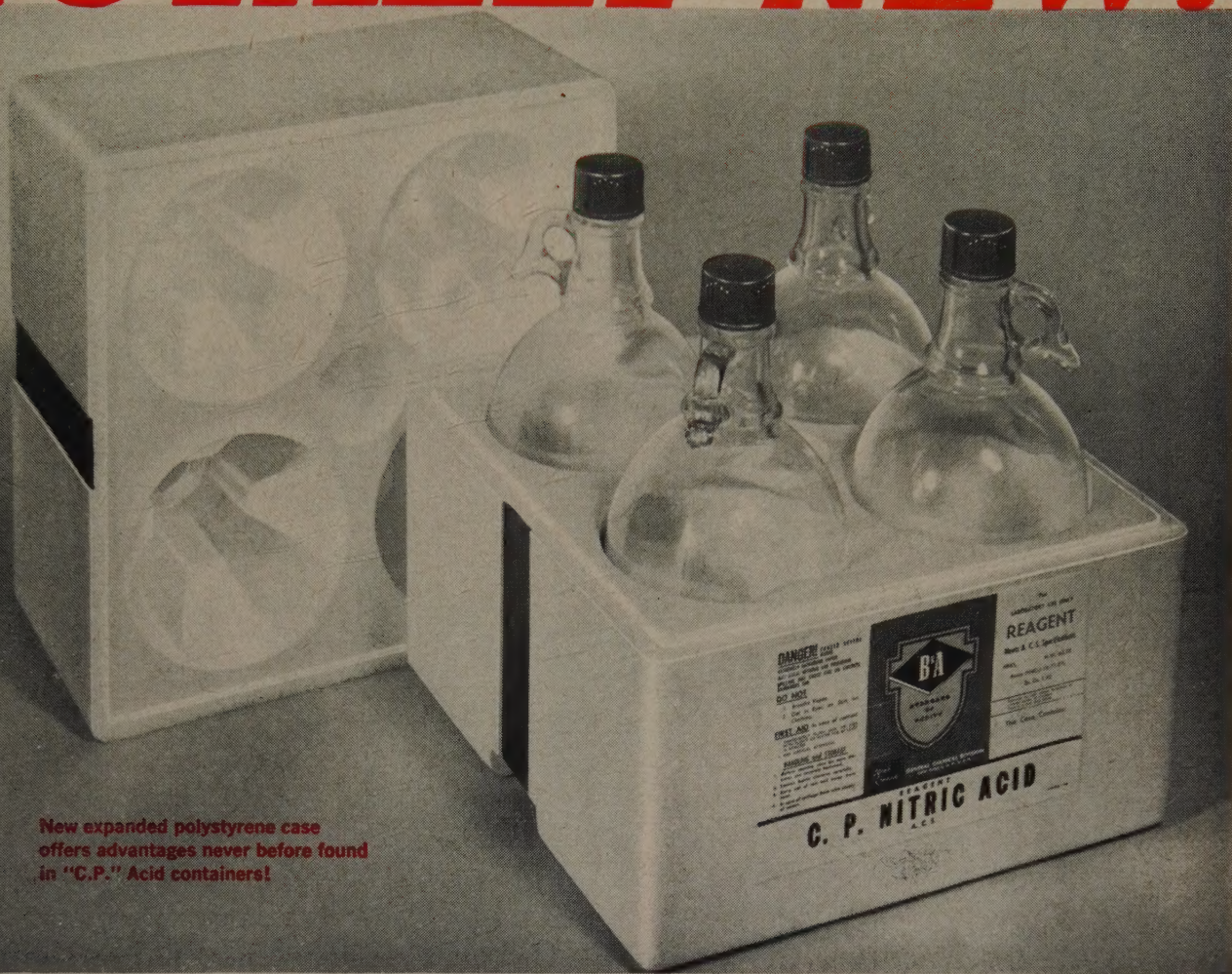
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New expanded polystyrene case offers advantages never before found in "C.P." Acid containers!

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**Easier to handle!** Convenient finger grips make case easy to lift and carry. Top and bottom specially designed with interlocking feature for safe stacking.

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**Order Now!** These new units are now ready for shipment from General Chemical's B&A distributing points coast to coast. They have had more than a year of intensive research and testing and are *proved* superior to any other type of "shipper" now available! For further information, phone or write your nearest B&A office.

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40 Rector Street, New York 6, N.Y.

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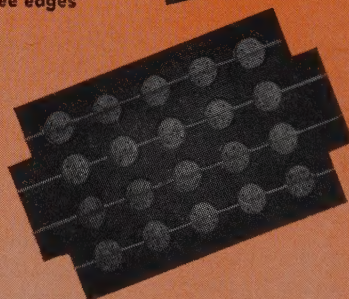
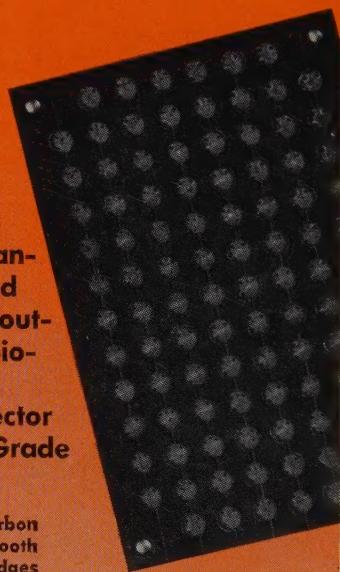
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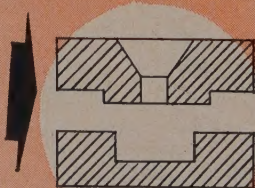
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typical configuration  
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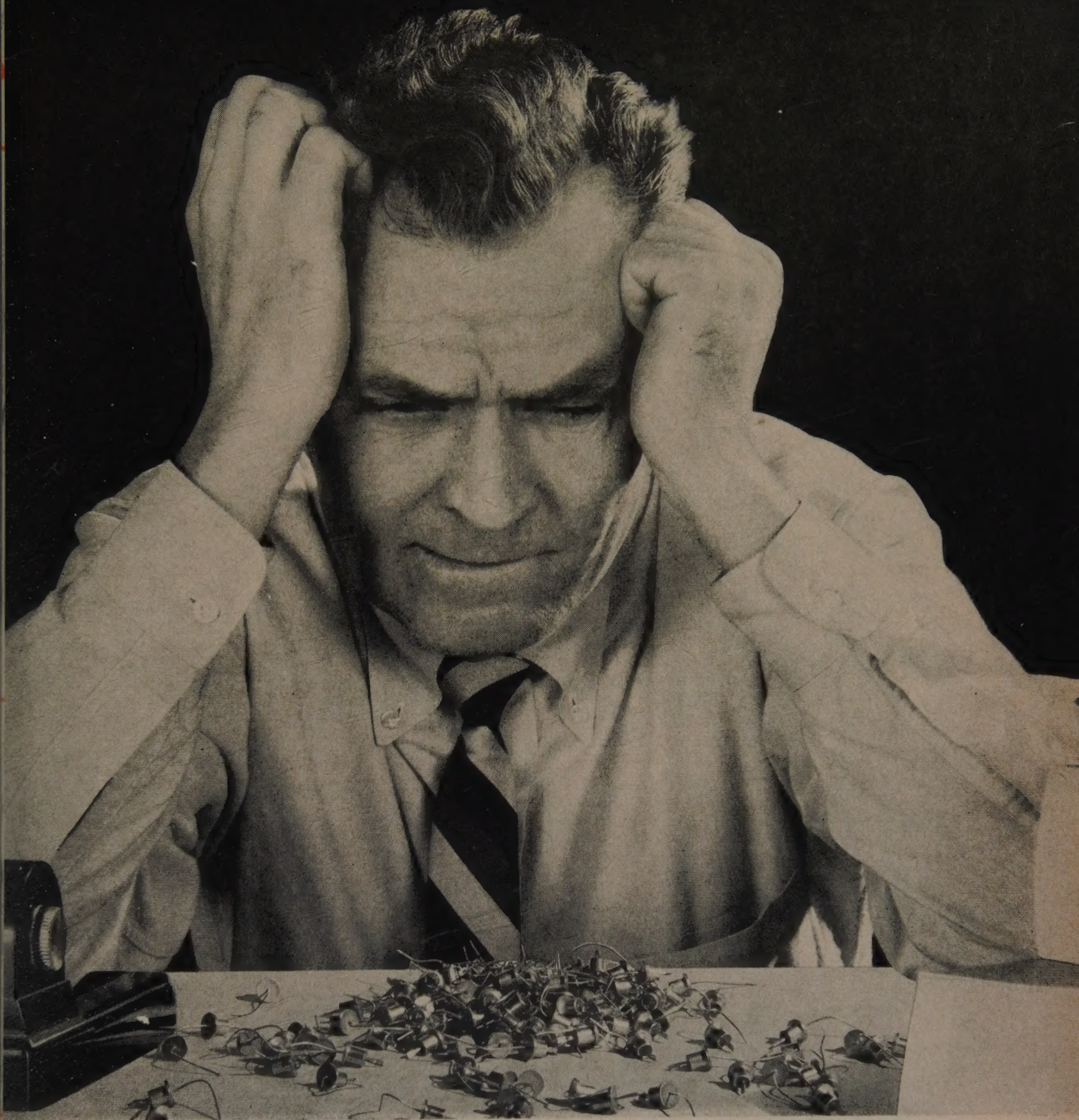
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One cause for low yields may be due to the use of compensated silicon crystals. With such compensated material, impurities can change from crystal to crystal and such changes are undetectable with standard control techniques.

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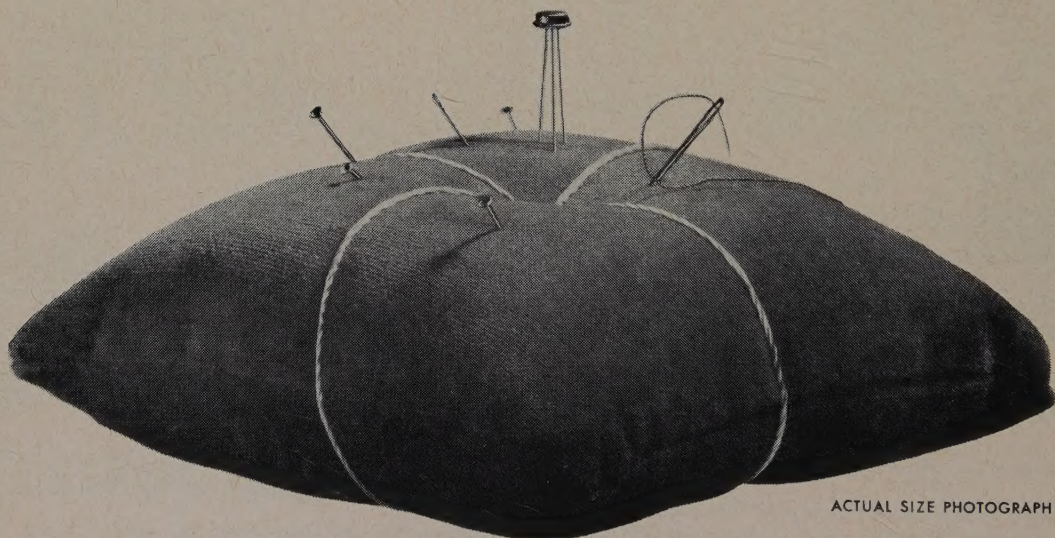
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AN  
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IN  
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WELDED  
MICRO-PACKAGE  
THIS  
SMALL!**



ACTUAL SIZE PHOTOGRAPH



# MICROBLOC RT697M

... Rheem's new solid-design silicon mesa transistor!

## WELDED HERMETIC SEAL

The MICROBLOC RT697M is the first micro-miniature silicon mesa transistor with a guaranteed welded hermetic seal. The glass sealing and welding techniques used in MICROBLOC production are the same techniques the industry has tested and perfected over the years, in the manufacture of millions of transistors. Each MICROBLOC is subjected to two hermetic seal tests—a helium leak test and a Joy bomb test—to insure a vacuum-tight seal.

## MICRO SIZE

The MICROBLOC RT697M is .063 inches flat, .211 inches in diameter, weighs only  $\frac{1}{4}$  gram, and occupies just  $\frac{1}{7}$ th the volume of the standard 2N697.

## IMPROVED ELECTRICAL CHARACTERISTICS

This new Rheem transistor has a three watt power dissipation—50% more than the standard 2N697. Result: cooler running junctions to assure wider safety margins and greater reliability. The MICROBLOC RT697M also has a 35 volt guaranteed minimum switchback voltage with base open, controlled small signal parameters and meets or exceeds every other specification of the 2N697.

## SOLID DESIGN

As its name suggests, MICROBLOC is virtually a solid block—a silicon crystal embedded in an optimum

dimensioned, gas tight, hermetically sealed, welded block that is essentially all heat sink. There are no fragilely suspended internal leads or non-integrated elements, and the crystal is protected from welding flash. Thus, the MICROBLOC RT697M design is mechanically more stable, more resistant to shock and vibration than any previous transistor. It will withstand at least 1,500 G shock and 20,000 G acceleration, and is guaranteed to survive thermal shock and temperature cycling per MIL-S-19500B. (Additional data will be published as more stringent tests are completed.)

## APPLICATION

The MICROBLOC RT697M is tailored for high-density applications, such as micro modules and miniature circuit boards. In addition, because of its cooler running junctions, it is an ideal improvement/replacement for standard size transistors in applications where wider safety margins and great reliability are required. (Rheem will also continue to offer its standard 2N697, TO-5 package, per MIL-S-19500/99A.)

## OTHER MICROBLOC TYPES

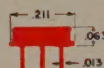
Rheem is now producing a complete new series of MICROBLOC silicon mesa transistors. There is a MICROBLOC type for every electrical function that can be performed by transistors up to a 1 amp. current level. For full details, see your Rheem representative.

## AVAILABLE IMMEDIATELY

### MAXIMUM RATINGS AT 25°C AMBIENT (unless otherwise noted)

|   |                 |
|---|-----------------|
| Collector--Base Voltage                           | 60 V            |
| Collector--Emitter Voltage (Base Open Circuit)    | 35 V            |
| Emitter--Base Voltage                             | 5 V             |
| Total Device Dissipation at case temperature 25°C | 3 W             |
| Operating Temperature Range                       | -65°C to +175°C |

All units are stabilized before testing at 300°C



**ENLARGED MICROBLOC OUTLINE**  
DIMENSIONS IN INCHES

### ELECTRICAL CHARACTERISTICS AT 25°C AMBIENT

| PARAMETERS              |   | TEST CONDITIONS |                         | MIN. | TYP.                 | MAX.                 | UNIT       |
|-------------------------|---|-----------------|-------------------------|------|----------------------|----------------------|------------|
| $I_{CBO}$               | Collector Reverse Current                         | $V_{CB} = 30v$  | $I_E = 0$               | —    | .005                 | 1.0                  | $\mu A$    |
| $h_{FE}$                | D-C Forward Current Transfer Ratio                | $I_C = 150ma$   | $V_{CE} = 10v$          | 40   | 75                   | 120                  | —          |
| $V_{CE(sat)}$           | Collector-Emitter Saturation Voltage              | $I_C = 150ma$   | $I_B = 15ma$            | —    | 0.7                  | 1.5                  | v          |
| $h_{fe}$                | A-C Common-Emitter Forward Current Transfer Ratio | $I_C = 50ma$    | $V_{CE} = 10v$ f = 20mc | 2.5  | 5                    | —                    | —          |
| $C_{ob}$                | Collector Capacitance                             | $I_E = 0$       | $V_{CB} = 10v$ f = 1mc  | —    | 20                   | 35                   | $\mu\mu f$ |
| SMALL SIGNAL PARAMETERS |   |                 |                         |      |                      |                      |            |
| $h_{fe}$                | Small Signal Forward Transfer Ratio               | $I_C = 1mA$     | $V_C = 5v$              | 30   | 70                   | —                    | —          |
| $h_{ib}$                | Common Base Input Impedance                       | f = 1KC         |                         | 20   | 26                   | 30                   | ohms       |
| $h_{rb}$                | Common Base Voltage Feedback Ratio                |                 |                         | —    | $160 \times 10^{-6}$ | $250 \times 10^{-6}$ | —          |
| $h_{ob}$                | Common Base Output Admittance                     |                 |                         |      | .2                   | 1.0                  | $\mu mhos$ |

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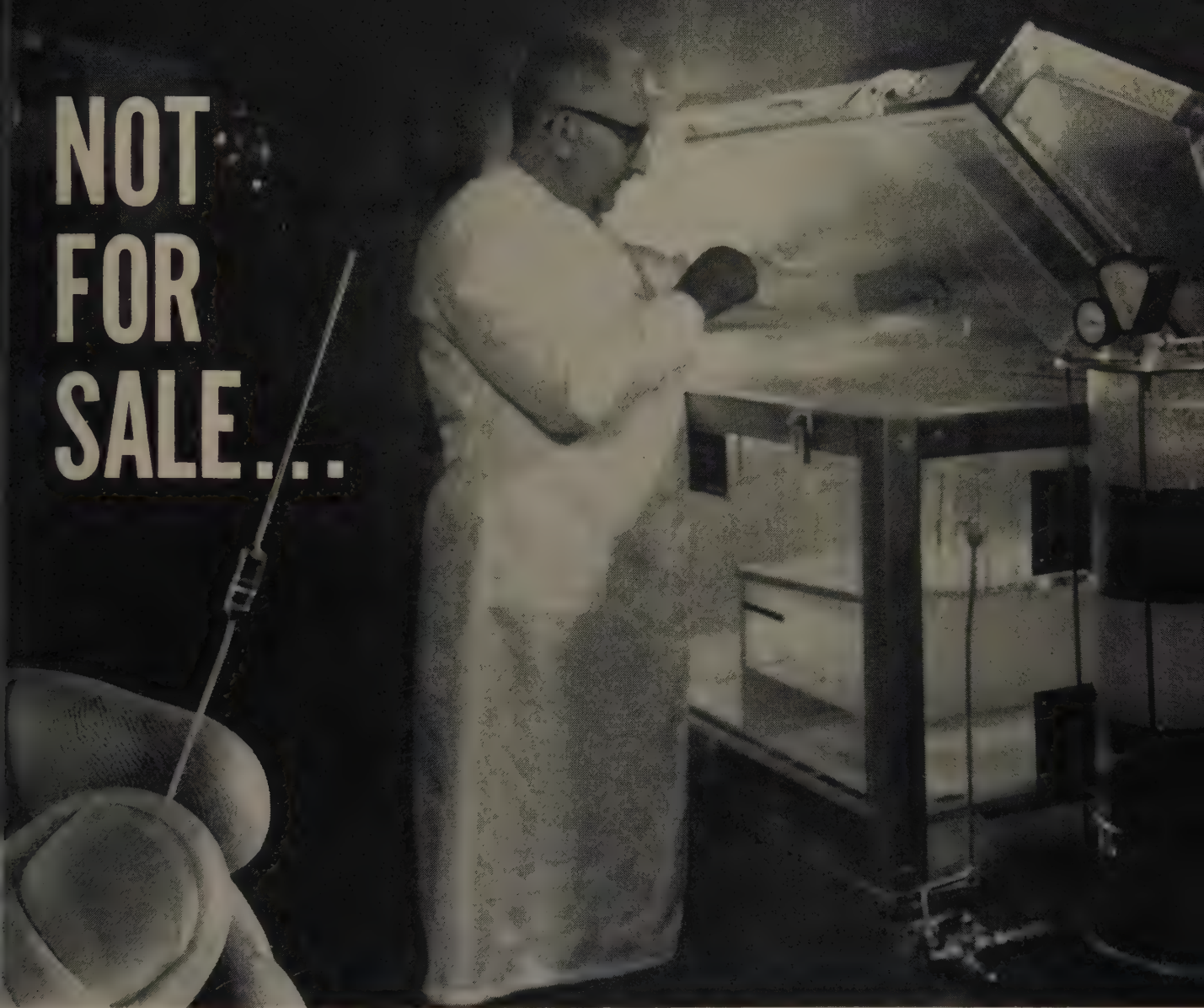
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\* Meet all requirements of MIL S-19500B

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not fully remove surface contamination and insure preform purity*

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## Alloys Unlimited protect the purity of

incident that Hamburg Tang's laboratory coat is white. It reflects the stress he puts on the preforms he makes as Chief Metallurgist at Alloys Unlimited. An achievement possible through the use of vapor degreasing and ultrasonic cleaning equipment.

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Asked as to whose preforms they prefer, the

187 engineers involved voted Alloys Unlimited "first choice."

Asked, "What are the factors influencing your choice?" the engineers answered, "Quality," "Purity," "Cleanliness."

If preform purity is as important to you as it is to the engineers participating in this survey—and you're not already using Alloys Unlimited products—then discover how switching can help improve your semiconductor device output. *Write for complete information.*



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# Some facts of supreme importance to manufacturers of semiconductor devices

*How leading producers capitalize on Alpha technology to increase their yield*

A number of major producers were already being supplied with aluminum spheres when they placed test orders for Alpha preforms. Result? Their percentage of usable silicon alloy diodes rose impressively. Today these companies are confirmed users of Alpha products.

In case after case, manufacturers who have switched to Alpha preforms of pure aluminum and aluminum alloys, as well as Alpha preforms of other metals and their alloys, report experiences as satisfactory as these.

## **It's the difference that counts!**

What makes Alpha aluminum preforms so unique? The care with which they are produced.

As with all Alpha products, aluminum and aluminum alloy discs, spheres, washers and cut wire segments go through repeated, rigorous quality controls and counter checks. Each lot is spectrographically analyzed for adherence to your purity specifications. Alpha's spectrographic check is so accurate, it reveals the presence of unwanted elements such as magnesium and manganese even when present in quantities as minute as 1 part per 1,000,000!

In addition to this purity check, each lot is analyzed by exact quantitative techniques. This safeguards the alloy's homogeneity. It also insures that the minor constituent is present in the precise amount required.

## **Check and double check**

Another indication of the care with which these aluminum preforms are made is the special microscopes Alpha uses to check dimensional accuracy. Spheres as large as  $\frac{1}{4}$ " and as small as .003" and discs and washers as thin as .0005" are checked for precise conformation to specifications.

As a further dimensional safeguard, a comparator casting an image 100 times the preform's actual size is used.

To assure freedom from surface contaminants, all Alpha preforms are processed through etching and vapor degreasing equipment. Every scintilla of foreign matter is effectively removed!

## **Only Alpha has it**

Alpha cut segments are produced in pieces as small as .008" dia. x .016" long. Alpha engineers designed and built the machinery to do this; *only Alpha has it!*

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## **Increasing your usable output**

These controls would satisfy most preforms suppliers—but not Alpha. Again and again, quality is controlled and checked by skilled technicians using the finest optical and mechanical equipment. The results reflect themselves in preforms of aluminum and other ultra high purity metals that, in case after case, increase the percentage of usable semiconductor devices.

Alpha preforms can help your output too. For current quotations on spheres, discs, cylinders, cubes, washers, rings and special shapes, write today. Describe alloys, dimensions and quantities wanted.

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Other Alpha products: Strip with Continuous Conductive Coating, high purity dots of silver, indium, cadmium, tin, lead and their alloys in shapes to your needs.

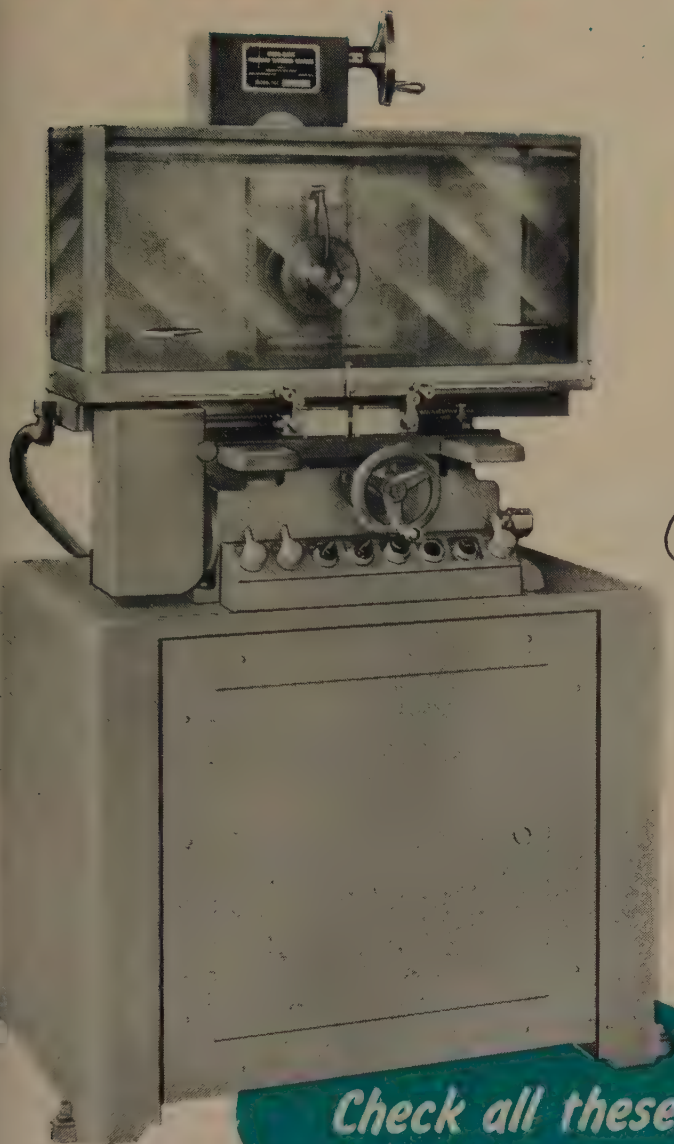
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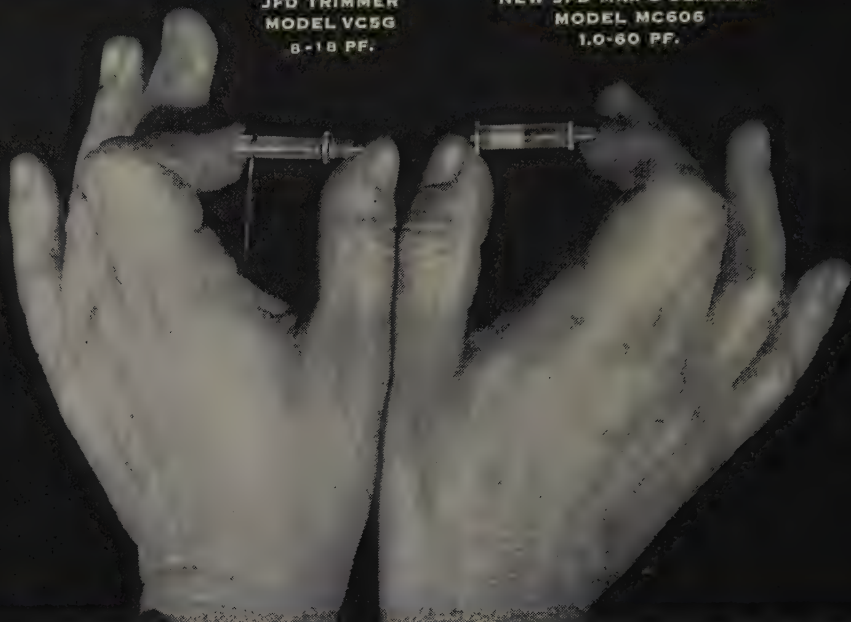


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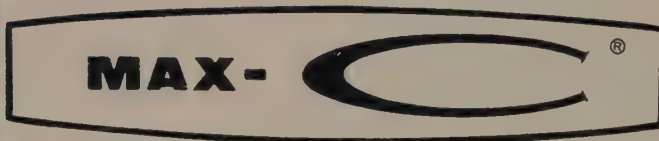
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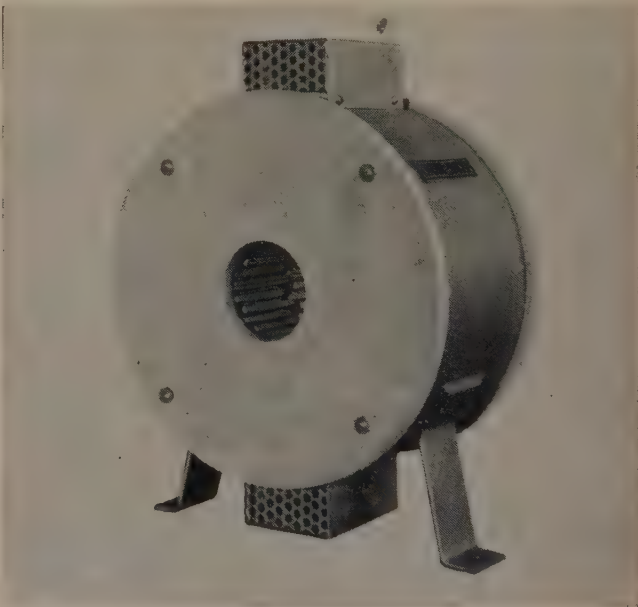


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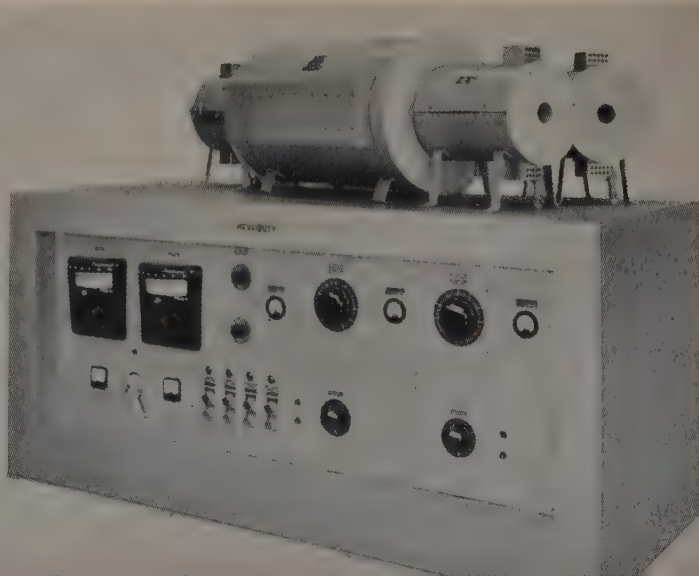
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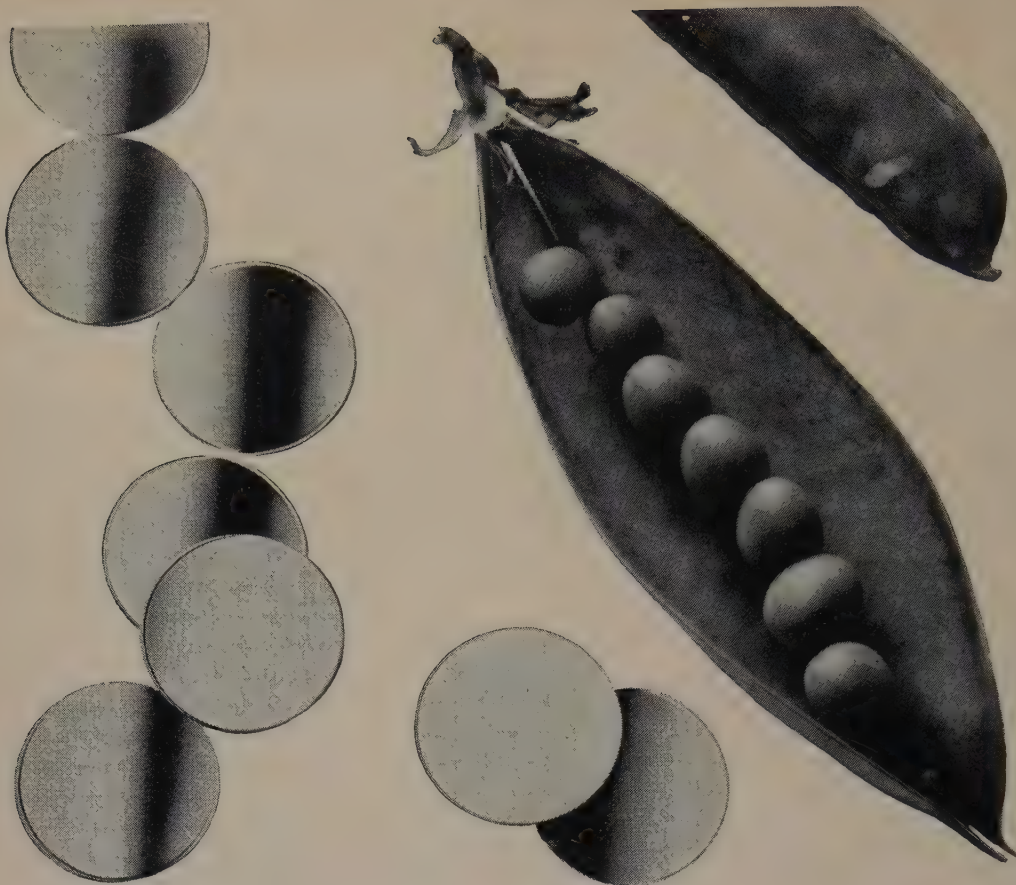


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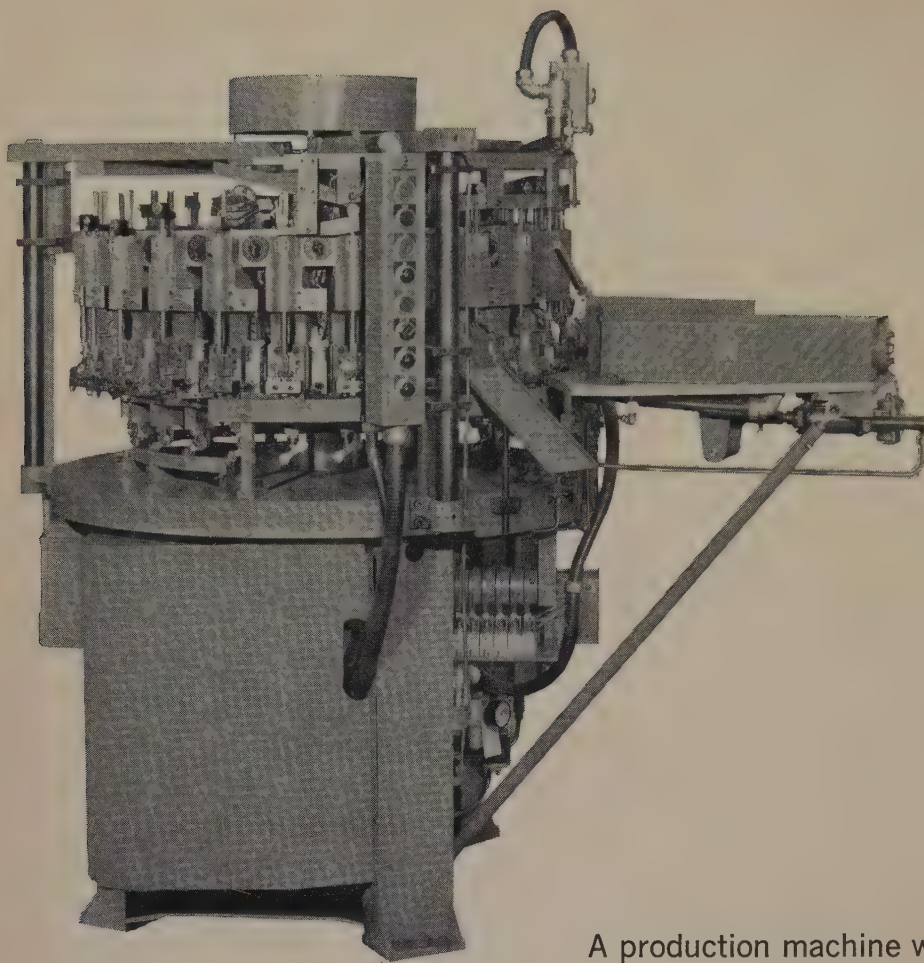


The diagram shows a circuit for testing a tunnel diode. A tunnel diode is connected in series with a 470 Ω resistor and a 470 pF capacitor. The circuit is driven by a +GATE OUT FROM C OSCILLOSCOPE. The output is connected to a TO 'N' UNIT SIGNAL INPUT. A 1000 Ω resistor is connected to the output. A 14KΩ resistor is connected to the input. A 310 resistor is connected to the input. A note indicates 'Value for 1-20 mΩ diodes' and 'APPROX. 3 h. RG58A/U'.



## 19





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# Editorial . . .

## Plasma Phenomena

The phenomena which arise from the interaction of electric and magnetic fields in plasma are extremely complex, not only because of their nature, but also because of the simultaneous occurrence of several fundamental processes. The investigations of J. J. Thomson, Townsend, Langmuir, and others, have clarified many of the aspects of gaseous discharges, such as the existence of ranges of the voltampere characteristics having negative slope, the dependence of the breakdown voltage upon the "equivalent" the breakdown voltage upon the "equivalent" interelectrode spacing and the ambient pressure been noted in the case of semiconductors in connection with effects at the  $p$ - $n$  junction and also with "bulk" conduction effects.

One of the interesting aspects of the electrical discharge is the presence of superposed random oscillations, which have the appearance of noise. In the case of reverse biased  $p$ - $n$  junctions, it has been shown that such oscillations correspond to the localized discharges which take place at imperfections of the lattice. The noise is produced by random pulses, which generally can be described in terms of the time intervals during which the discharge is "on" or "off" and also in terms of the peak or of the average current. When the external load impedance is low, the resulting distribution is of Markoff type with asymptotic spectral dependence of the type  $\omega^{-2}$ . When the load impedance is large, the "on" and "off" time intervals are interrelated and the interpretation of the nature of the noise becomes

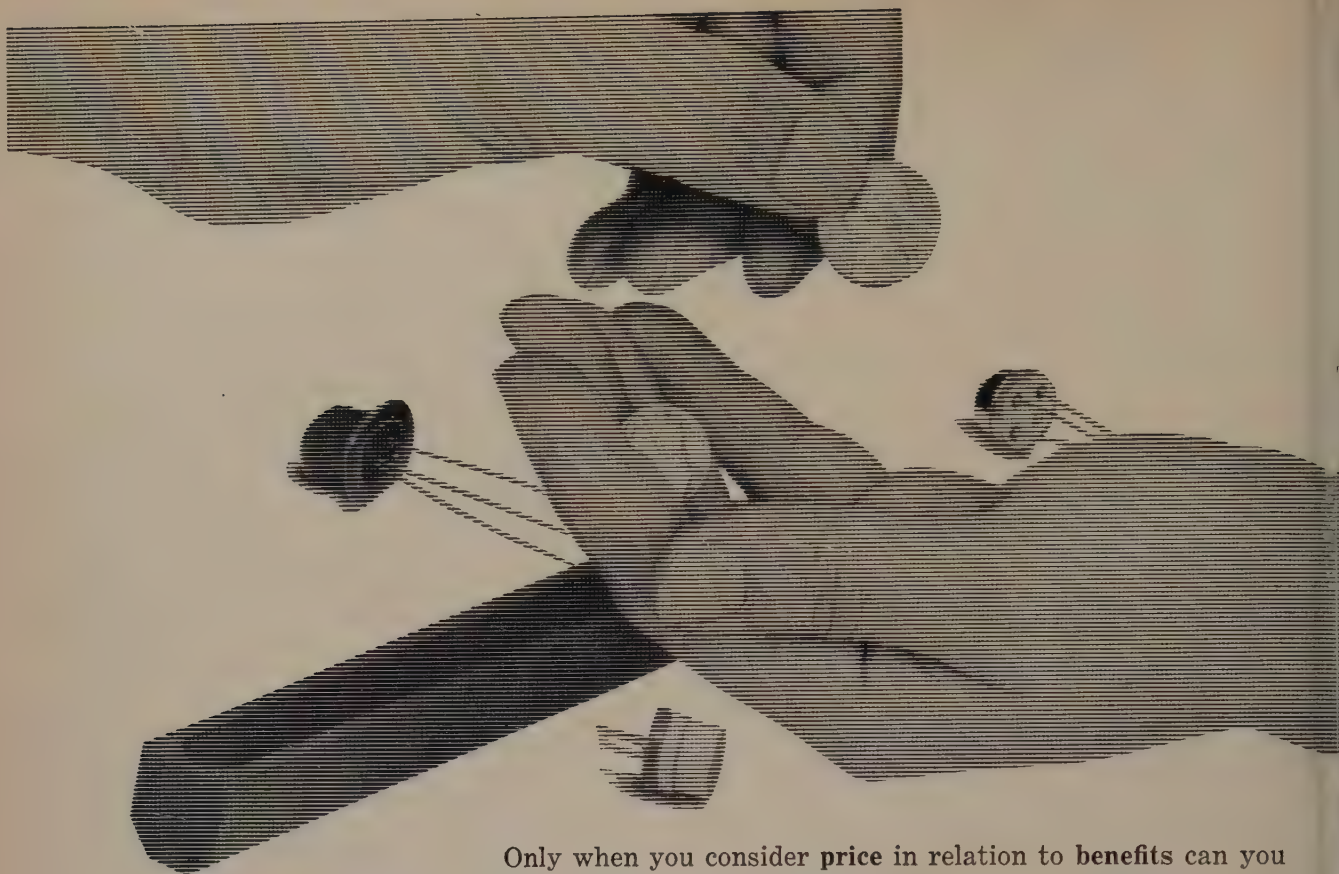
more complex.

Random oscillations are also obtained when a magnetic field is applied in a direction parallel to that of the current. Again these phenomena are found both in gaseous discharges and in semiconductors, although they differ in their characteristics and frequency ranges. Larrabee and Steele (*J.A.P.—September 1960*) have given a detailed investigation of the latter, using specimens of  $n$ - and  $p$ - type germanium, silicon and indium-antimonide. The effects are observed with (pulsed) currents of the order of 100 to 1000 A/cm<sup>2</sup> and with parallel magnetic fields of the order of 10,000 gauss. When a transversal component of the magnetic field is also present, the output oscillations tend to become sinusoidal of single frequency in the range of few kc/s to about 10 Mc/s. One of the possible explanations of the generation of the oscillations is based on the effect of the surface recombination velocity, which is a function of the carrier density near the surface. If the said velocity decreases with the increase of the carrier density, it is possible that an unstable equilibrium is realized between forces tending to push the plasma against the surface and diffusion fields which tend to counteract them.

The complexity of plasma phenomena is probably due to still imperfect understanding. However, the great promise that they present for applications and for the development of novel devices is attracting intensified research in many groups engaged in R&D.

Samuel L. Marshall





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# Transistor Choppers

J. A. EKISS\*

The transistor is finding wide application in chopper applications where it is desired to convert a low level *d-c* signal to an *a-c* voltage. In this application the transistor functions as a switch. This article is concerned with how the transistor should be characterized for this switching application and what transistor parameters influence performance. Several simple modulator and demodulator circuits are discussed which illustrate how the transistor is utilized in this application.

IN SERVO-MECHANISM CONTROL SYSTEMS, analog computers, and instrument recorders there is often the need to convert a *d-c* (or low frequency) voltage to an *a-c* signal. The resulting chopped voltage may then be amplified by a conventional *a-c* amplifier. In theory this conversion of a *d-c* signal to an *a-c* signal may be accomplished by opening and closing a switch in such a manner that the signal is first switched across a load and then removed. The wave form of the *a-c* signal across the load will be a function of the wave form of the applied signal and the properties of the device used as the switch.

Certain types of transistors make excellent switches, i.e., they have two states: one in which they are conducting and one in which they are non-conducting. This switching action is entirely analogous to the operation of a conventional electrical switch.

This article will characterize the transistor as a chopper and describe practical circuits for use in chopper applications.

## Theoretical Considerations

### Operating Regions

Transistor choppers utilize both the common emitter and the inverted connection (obtained by using the emitter as the collector and the collector as the emitter) depending on the intended application. For purposes of discussion let us assume that the common emitter connection is being used. (The following discussion is also valid for the inverted connection if words "emitter" and "collector" are interchanged.)

The transistor switch is characterized by three regions of operation. These are shown on the collector characteristics in Fig. 1. Region I corresponds to collector current cut-off (emitter and collector junction reverse biased); Region II is the active region (emitter forward biased and collector reverse biased); Region III corresponds to collector current saturation (emitter and collector junctions forward biased).

From Fig. 1 and the above definitions, we see that operation in Region I corresponds to an open switch and operation in Region III corresponds to a closed switch. Region II is a transition region between the open and closed conditions.

### Offset Voltage and Current

The transistor is not a perfect switch, since when it is closed it has a finite voltage drop across it and when the switch is open it has a finite leakage current flowing through it. The voltage drop across the transistor when it is "on" (switch closed) is referred to in the literature as the "offset voltage",  $V_p^{(1)}$ ; the leakage current that flows in the transistor when it is "off" (switch open) is referred to as the "offset current",  $I_p$ .

1. The quantities  $V_p$  and  $I_p$  were originally defined by R. L. Bright in "Junction Transistors Used as Switches".  $V_p$  was defined as the collector-to-emitter voltage when the transistor was turned on with 1 ma. of base current.  $I_p$  was defined as the collector (or emitter) current when the transistor was turned off with a base to emitter voltage of 1 volt. In this article  $V_p$  is defined as the collector-to-emitter voltage when the transistor is conducting;  $I_p$  is defined as the collector (or emitter) current when the transistor is non-conducting.

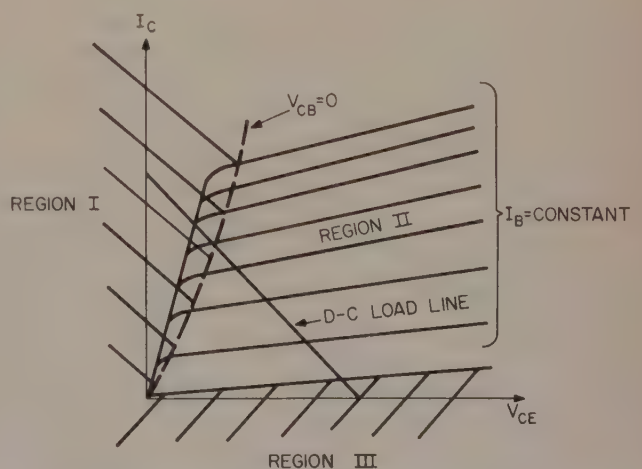


Fig. 1—The three regions of operation of the transistor chopper.

\*Applications Engineer, Lansdale Tube Company, Lansdale, Pa.



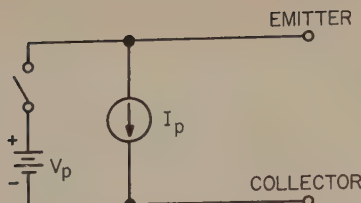


Fig. 2—Approximate equivalent circuit for the transistor chopper.

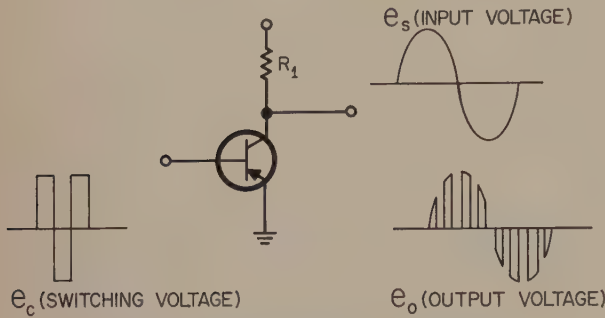


Fig. 3—Simple transistor modulator.



Fig. 4—The ideal transistor.

An approximate equivalent circuit for the transistor when used as a chopper thus consists of a perfect switch in series with a voltage source  $V_p$  and shunted by a current source as shown in Fig. 2.

The simple modulator<sup>(2)</sup> shown in Fig. 3 will illustrate the effect of  $V_p$  and  $I_p$  on chopper performance. When the transistor is conducting we desire the output to be zero. When the transistor is non conducting we desire the output to be equal to the instantaneous value of the input signal. From the previous discussion of offset voltage and current it is evident that when the transistor is "on" the output will be  $V_p$ . In the "off" state the output will not be equal to the input signal but will be:

$$e_o = e_s - I_p R_1.$$

This shows that  $V_p$  and  $I_p$  limit the lowest magnitude of signal which may be chopped.

Therefore, in order to obtain an output voltage from the modulator proportional to the input signal, the effects of  $V_p$  and  $I_p$  must be minimized. The magnitude of  $V_p$  and  $I_p$  can be minimized by selection of certain

transistors that have inherently low  $V_p$  and/or  $I_p$  and by utilization of the inverted connection previously described. The effects of given  $V_p$  and  $I_p$  values may be minimized by careful circuit design.

$V_p$  and  $I_p$  may be related to fundamental transistor parameters. If we look at expressions for  $V_p$  and  $I_p$  in terms of these parameters, insight may be gained into the problem of how to select transistors for chopper applications.

Consider the "ideal transistor" of Fig. 4 which has no spreading resistance associated with it. We will also assume that the base width is not dependent upon the collector voltage.

With the polarity for currents as shown, the following equations may be written relating  $I_C$  and  $I_E$  to the collector-to-base voltage,  $V_C$ , and the emitter-to-base voltage,  $V_E$ <sup>(3)</sup>:

$$I_E = \frac{I_{E0}}{1 - \alpha_N \alpha_I} \left( e^{\frac{q V_E}{kT}} - 1 \right) + \frac{\alpha_I I_{C0}}{1 - \alpha_N \alpha_I} \left( e^{\frac{q V_C}{kT}} - 1 \right) \quad (1)$$

$$I_C = + \frac{\alpha_N I_{E0}}{1 - \alpha_N \alpha_I} \left( e^{\frac{q V_E}{kT}} - 1 \right) - \frac{I_{C0}}{1 - \alpha_N \alpha_I} \left( e^{\frac{q V_C}{kT}} - 1 \right) \quad (2)$$

In these equations

$I_{E0}$  = saturation current of the emitter diode when  $I_C = 0$ .

$I_{C0}$  = saturation current of the collector diode when  $I_E = 0$ .

$\alpha_N$  = D-C alpha of the transistor with the collector functioning as a collector and the emitter as an emitter (normal  $\alpha$ ).

$\alpha_I$  = D-C alpha of the transistor with the emitter functioning as the collector and the collector functioning as the emitter (inverted  $\alpha$ ).

$q$  = charge of electron.

$k$  = Boltzmann's constant

$T$  = absolute temperature ( $^{\circ}\text{K}$ ).

$V_C$  = collector-to-base voltage, defined as positive from collector-to-base.

$V_E$  = emitter-to-base voltage, defined as positive from emitter-to-base.

In addition to Equations (1) and (2)

$$\alpha_N I_{E0} = \alpha_I I_{C0} \quad (3)$$

The offset current corresponds to  $I_C$  when both the emitter and collector junctions are reverse biased. This current, denoted by  $I_p^N$ , is found by combining Equations (2) and (3) under the conditions that

$$e^{\frac{q V_E}{kT}} \ll 1 \quad (4)$$

$$e^{\frac{q V_C}{kT}} \ll 1 \quad (5)$$

2. A modulator is defined as a device that converts d-c to a-c; a demodulator is defined as a device that converts a-c to d-c.

3. J. J. Ebers and J. L. Moll, "Large-Signal Behavior of Junction Transistors", *Proc. I.R.E.*, December 1954.



Thus,

$$I_p^N = \frac{(1 - \alpha_I) I_{C0}}{1 - \alpha_N \alpha_I} \tag{6}^{(4)}$$

The offset current for the inverted connection follows from Equation (6) by interchanging the superscripts "N" and "I" and replacing  $I_{C0}$  with  $I_{E0}$ .

$$I_p^I = \frac{(1 - \alpha_N) I_{E0}}{1 - \alpha_N \alpha_I} \tag{7}$$

For non symmetrical<sup>(5)</sup>, homogenous base transistors  $\alpha_N > \alpha_I$  and  $I_{E0} < I_{C0}$ . Inspection of Equations (6) and (7) thus shows that  $I_p^I < I_p^N$ .  $I_p^I$  may be as much as two orders of magnitude less than  $I_p^N$ . Equations (6) and (7) also indicate that small  $I_p$  may be achieved by keeping  $I_{E0}$  and  $I_{C0}$  small. This dictates the use of silicon transistors for applications where  $I_p$  must be minimized.

The offset voltage for the common emitter connection is  $V'_{CE}$  when the transistor is driven into the saturation region. The quantity  $V'_{CE}$  is defined in Fig. 5. Here,  $r'_c$  and  $r'_e$  are ohmic spreading resistances associated with the emitter and collector regions, respectively. From Fig. 5

$$V'_{CE} = I_C r'_c - I_E r'_e + V_{CE} \tag{8}$$

Using Equations (1), (2), and the fact that

$$I_B + I_C + I_E = 0 \tag{9}$$

one obtains:

$$V_{CE} = -\frac{kT}{q} \ln \frac{1}{\alpha_I} - \frac{kT}{q} \ln \frac{1 + \frac{\alpha_I}{\alpha_N} \frac{I_{C0}}{I_B} + \frac{I_C}{I_B} (1 - \alpha_I)}{1 + \frac{I_{C0}}{\alpha_N I_B} + \frac{I_C}{I_B} \left(1 - \frac{1}{\alpha_N}\right)} \tag{10}$$

The offset voltage is obtained by combining Equations (8), (9), and (10). This yields:

$$V_p^N = I_C (r'_c + r'_e) + I_B r'_e - \frac{kT}{q} \ln \frac{1}{\alpha_I} - \frac{kT}{q} \ln \frac{1 + \frac{\alpha_I}{\alpha_N} \frac{I_{C0}}{I_B} + \frac{I_C}{I_B} (1 - \alpha_I)}{1 + \frac{I_{C0}}{\alpha_N I_B} + \frac{I_C}{I_B} \left(1 - \frac{1}{\alpha_N}\right)} \tag{11}^{(4)}$$

For applications where the input signal is small (low-level chopper) and the transistor is driven hard into saturation, Equation (11) reduces to:

$$V_p^N \cong I_B r'_e - \frac{kT}{q} \ln \frac{1}{\alpha_I} \tag{12}$$

4. In Equations (6) and (7)  $\alpha_N$  and  $\alpha_I$  are measured in the cut-off region (Region I).  
5. A non symmetrical transistor is defined here as one in which the collector junction area is larger than the emitter junction area.  
6. The  $\alpha_N$  and  $\alpha_I$  in this equation are to be measured at the "edge" of the saturation region.

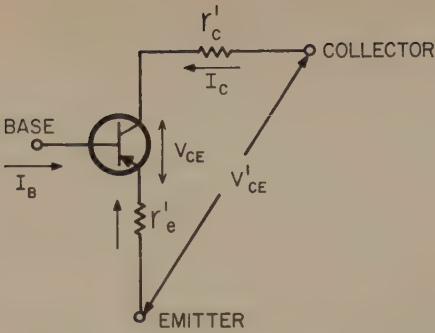


Fig. 5—The ideal transistor with spreading resistances.

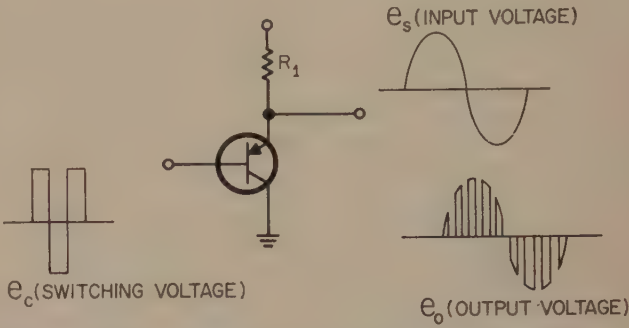


Fig. 6—Transistor modulator using the inverted connection.

For the inverted connection, the offset voltage is

$$V_p^I \cong I_B r'_c - \frac{kT}{q} \ln \frac{1}{\alpha_N} \tag{13}$$

Equations (12) and (13) show that if  $r'_c \cong r'_e$ ,  $V_p^I < V_p^N$ , since  $\alpha_I < \alpha_N$ . Thus the use of the inverted connection leads to a lower offset voltage.  $V_p^N$  is minimized by keeping the emitter spreading resistance small,  $\alpha_I$  large, and  $I_B$  (the base driving current) as small as practicable;  $V_p^I$  is minimized by small  $r'_c$ , large  $\alpha_N$ , and small  $I_B$ .

At this point it may be well to emphasize the fact that not only do  $V_p$  and  $I_p$  depend on transistor parameters but they also depend on the operating conditions under which they are measured. The expressions shown for  $I_p$  Equations (6) and (7) are voltage dependent since  $I_{C0}$  and  $I_{E0}$  contain leakage components which are voltage dependent. The dependence of  $V_p$  on operating conditions is explicit to some degree in Equations (12) and (13).  $V_p$  is dependent on  $I_B$ ,  $I_p$  and  $V_p$  are, of course, temperature dependent.  $I_{C0}$  and  $I_{E0}$  approximately double for each 10° C increase in temperature. Since  $\alpha_I$  and  $\alpha_N$  increase slightly with temperature,  $V_p$  increases only slightly with temperature. When  $V_p$  and  $I_p$  are specified, the conditions under which the measurements are made should be given.

### Practical Applications

#### Circuits

The circuit shown in Fig. 3 is one form of modulator that may be used in conjunction with an a-c amplifier



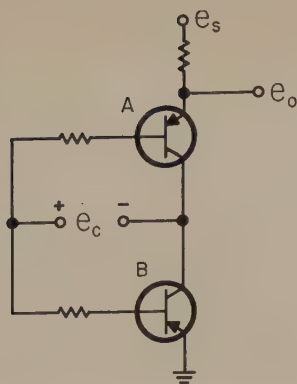


Fig. 7—Modulator circuit which will chop a-c signals.

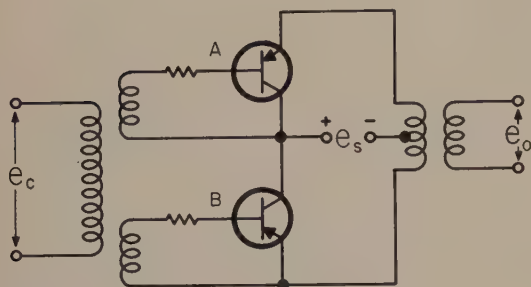


Fig. 8—Modulator circuit in which the offset voltages cancel.

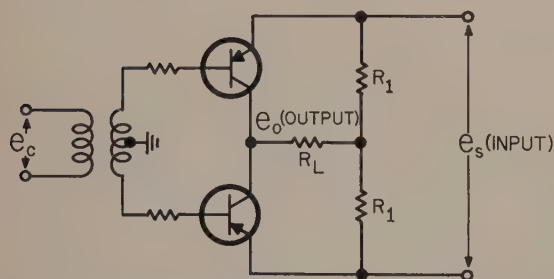


Fig. 9—A modulator circuit which is balanced with respect to offset voltage and current.

to form a *d-c* amplifier, for use (for example) in an analog computer. The output when the transistor is conducting is  $V_p^I$  while the output when the transistor is non conducting is  $e_s - I_p^I R_1$ . Thus,  $V_p^I$  and the product  $I_p^I R_1$  must be minimized if the chopped output is to be proportional to the input. When the chopper is used to modulate very low input voltages, the inverted connection should definitely be used. If circuit design necessitates the need for a large  $R_1$ , silicon transistors should be utilized in this circuit because of their low  $I_p^I$ . If  $R_1$  may be kept small so that  $V_p^I$  is large with respect to  $I_p^I R_1$ , germanium transistors should be used because their  $V_p^I$  is generally lower than  $V_p^I$  of silicon.<sup>(7)</sup> One disadvantage of this circuit is that it will not chop positive input signals greater than the base-to-collector voltage holding the transistor off. This is not a serious disadvantage except in

applications where the signal to be chopped is large.

A novel circuit<sup>(8)</sup> that may be used to chop *a-c* input signals is shown in Fig. 7.  $e_c$  is a square wave switching voltage with instantaneous polarity as shown,  $e_s$  is the *a-c* input signal to be modulated. With the polarities as shown transistor B is cut-off so the output is approximately equal to the input signal. If  $e_c$  is large enough ( $e_c > 1$  volt), then transistors A and B may be represented as two current sources  $I_{pA}^I$  and  $I_{pB}^I$  which are of opposite polarity, thus tending to cancel one another out. The output voltage will thus be

$$e_o = e_s - (I_{pA}^I - I_{pB}^I) R_1. \quad (14)$$

We see that the offset currents tend to cancel.

If the polarity of the chopping voltage,  $e_c$ , is reversed, both transistors will conduct. Transistors A and B may be represented as two batteries in series of magnitude  $V_{pA}^I$  and  $V_{pB}^I$ . These voltages are of opposite polarity and hence tend to cancel. The output voltage for this half cycle of  $e_c$  is

$$e_o = V_{pB}^I - V_{pA}^I. \quad (15)$$

With proper selection of transistor pairs, the effects of  $V_p$  and  $I_p$  may be minimized. Transistors should be selected on the basis of matched offset voltages rather than attempting to match offset current.  $I_p$  is quite temperature sensitive so matching at one temperature would not guarantee cancellation of offset current. Furthermore, there is some control on the effect of  $I_p$  through the resistance  $R_1$ .

There is some possibility to control the magnitude of  $V_p$  as inspection of Equations (12) and (13) show.

$$V_p^I = I_B r'_c - \frac{kT}{q} \ln \frac{1}{\alpha_N} \quad (13)$$

The magnitude of  $V_p^I$  may be adjusted by changing  $r'_c$  with external resistance. This method of balancing will work if  $I_B$  is regulated.

A modulator circuit<sup>(9)</sup> in which the offset voltages cancel is shown in Fig. 8.  $e_c$  is a square wave switching voltage;  $e_s$  is the *d-c* input signal. With transistor "A" conducting, the output,  $e_{out}$ , will be  $e_s - V_{pA}$  (for a total primary to secondary turns ratio of 2:1). With transistor "B" conducting and transistor "A" cut-off the output is  $e_s + V_{pB}$ . Therefore, the peak-to-peak output voltage is  $e_s$  provided  $V_{pA} = V_{pB}$ .

$e_s$  can be no larger than the magnitude of the base-to-collector voltage holding the transistor off.

As a final example of the use of transistors as choppers, a demodulator circuit is shown in Figure 9.<sup>(10)</sup>

7. That  $V_p^I$  for germanium transistors is generally less than  $V_p^I$  for silicon transistors follows from the fact that  $B_N$  of silicon units is, in general, less than  $B_N$  for germanium units.
8. R. L. Bright "Junction Transistors Used as Switches", Paper 55-156, *Transactions of the AIEE*; March, 1955.
9. See A. J. Williams, et al, "Some Advances in Transistor Modulation for Precise Measurement", Leeds and Northrup Company, Philadelphia, Pa.
10. See L. P. Hunter, "Handbook of Semiconductor Electronics", McGraw-Hill Book Co., New York, N. Y.; 1956.



This circuit is used to convert the *a-c* input signal to a *d-c* output proportional to the input. For the circuit to function properly, the square wave switching voltage,  $e_c$ , must be either in phase with the input signal or  $180^\circ$  out of phase with it. The circuit is balanced with respect to the offset voltage and current so that the *d-c* output due to these quantities is minimized. (See Fig. 10.)

If we define  $e_{01}$  as the output due to  $V_{pA}^I$ , then the output due to these quantities<sup>(11)</sup> ( $e_c = 0$ ) is:

$$e_{01} = \frac{R_L}{R_1 + R_L} V_{pA}^I - \frac{R_L R_1}{R_L + R_1} I_{pA}^I \quad (16)$$

Similarly, when transistor "B" is conducting,

$$e_{02} = \frac{R_L}{R_1 + R_L} V_{pB}^I - \frac{R_L R_1}{R_L + R_1} I_{pB}^I \quad (17)$$

Thus, these components of the output may be minimized by selection of transistors and adjustments of  $R_L$  and  $R_1$ . In particular for  $R_L = R_1 = V_p/I_p$ ,  $e_{01} = e_{02} = 0$ .

#### Summary of Considerations in the Selection of Transistors for Chopper Applications

1. For low level applications where very small signals are being chopped, particular attention must be given to  $V_p$  and  $I_p$ . We have seen that silicon transistors have a lower offset current than germanium transistors. Thus, in applications where  $I_p$  is important, silicon transistors should be employed. In applications where  $V_p$  is of primary importance, germanium transistors should be used.
2. In applications where the signals to be chopped are

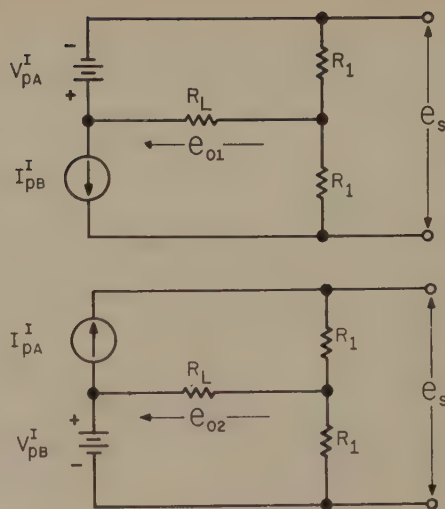


Fig. 10—Equivalent circuits for the demodulator for one cycle of the switching voltage.

much larger than the offset quantities, germanium units should be used.

3. In addition to the above two comments transistors used in high frequency choppers must have good high frequency switching characteristics. The rise, fall, and storage times should be small with respect to the reciprocal of the frequency of the modulating voltage. In general, the frequency of the modulating voltage should be at least ten times the frequency of the input signal.

11. The assumption is made here that the input voltage is derived from a high impedance source.

## Resistivity, Crystal Perfection, and Lifetime Measurements for Germanium and Silicon Monocrystals

DR. A. S. TULK\*

Present developments in the semiconductor industry include increased reliance of device manufacturers on sources of monocrystals other than their own materials department. One of the problems which must be faced by the purchaser of crystals from an "outside" source is the degree of trust which he can place in the evaluation by the supplier. Not only must the identity of the measurement be known to the purchaser, but much of the detail of the measurement method must also be familiar to him.

In the subsequent discussion, a measuring procedure for germanium and silicon monocrystals will be outlined in considerable detail.

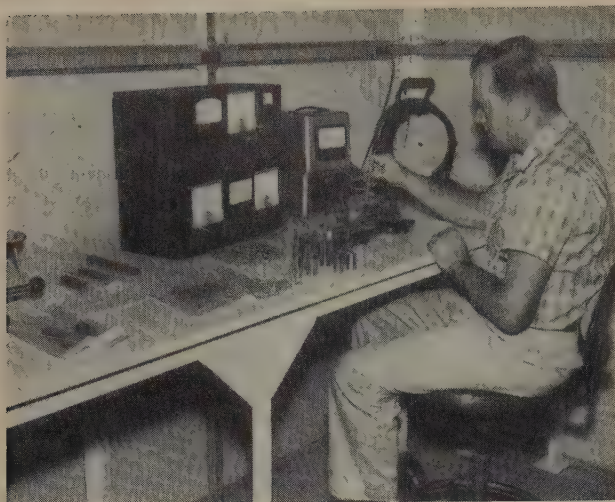
#### Germanium Resistivity

The surface on which the resistivity readings are taken must be smooth and abraded. If a diamond cut-off wheel is used to cut the crystal to length, the surface is usually satisfactory. A flat area about one centimeter in width is ground along the side of the crystal with a diamond wheel if readings are to be made longitudinally.

A measurement is made along the side of a mono-

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The determination of the resistivity profile of a silicon monocrystal by means of the two-point probe. The current is supplied to the crystal from the power supply at the left, and potential between the probes is read on the vacuum-tube voltmeter in the center.

crystal only when a complete profile is desired. This is accomplished by the two-point-probe method at regular intervals. It is more usual to take readings on the ends of the crystal with a four-point probe. From five to ten such readings are made about the center of the cut face and the low reading is recorded.

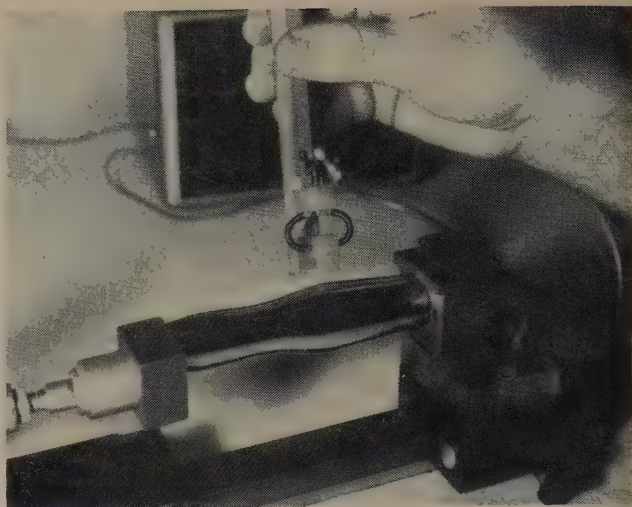
A similar number of readings are then taken near the outer edge of the crystal. The probes are aligned along the radii of the crystal and care is taken to place the outermost probe no closer than six millimeters from the edge of the face. The highest reading of this group is recorded.

All the readings must be within the desired specification. If any are not, a slice, several millimeters thick, is cut from the faulty end and the readings are repeated.

All measurements are made in an electrically shielded room whose temperature is maintained at 27°C (300°K). Because the resistivity of intrinsic germanium is very sensitive to temperature, crystals whose resistivities approach theoretical are allowed to remain in the measuring room for at least two hours to ensure thermal equilibrium.

The probes used in the four-point-probe method are made of tungsten or hardened steel. These are accurately positioned in a straight line, 0.050 inch apart. The current passed through the outer probes is 0.80 milliamperes and the resistivity is read directly by means of a Millivac vacuum-tube voltmeter (Model 17-C or 27-C) between the inner probes.

When a two-point scan is made along the side of the germanium monocrystal, a vise with insulated end contacts of lead is used to hold the piece. A current of about one milliamperes is passed through the crystal. With highly doped crystals it is often necessary to use a higher current to increase the potential drop from point to point to a measurable value. These probes are also made of tungsten or hardened steel



Close-up of the two-point probe being used on a silicon monocrystal. The tungsten probes are applied to the crystal along an abraded strip. The lead-faced jaws of the clamp make the current contacts to the crystals.

and are spaced 0.030 inch apart. The potential between them is read by the vacuum-tube voltmeter described above. The resistivity is then calculated from the equation:

$$\rho = \frac{E}{I} \times \frac{A}{d},$$

in which  $E$  is the measured potential ( $mv$ ),  $I$  is the current ( $ma$ ),  $A$  is the cross-sectional area ( $cm^2$ ), and  $d$  is the probe spacing ( $cm$ ).

### Silicon Resistivity

All resistivity measurements on silicon monocrystals are made by the two-point-probe method. The ends of the crystal are cut off and the cut faces are made parallel to each other with a diamond cutoff wheel. A narrow flat strip is ground along one side of the crystal with a diamond grinding wheel and the crystal is clamped in the lead-faced vise.

The two-point probe described for germanium is used and readings are taken at one-centimeter intervals. The lowest possible current is used through the crystal. This is usually in excess of one milliamperes, however. The calculations are the same as those used for germanium.

Because of the difficulty encountered in making ohmic contacts to silicon, readings are checked with the current direction reversed. If the two sets of readings do not agree, the ends of the crystal are recut and the measurements repeated.

All silicon monocrystals are checked for the presence of photovoltaic effects which are usually associated with steep impurity gradients in the crystal. All leads are removed from the vise and the probe is placed in contact with the silicon. If a reading is obtained on the vacuum-tube voltmeter, it is recorded and compared to the readings made for resistivity calculations. If a photovoltage is observed which exceeds five percent of the voltage read when current



is flowing, the resistivity determination is in doubt and the crystal is rejected. Photovoltages are usually not encountered on fairly heavily doped silicon monocrystals.

### Germanium Crystal Perfection

Crystal perfection is studied on a  $\langle 111 \rangle$  face. Slices, one to three millimeters in thickness, are cut from each end of the crystal. The side of the slice which was next to the main part of the crystal is lapped on a flat glass plate with a water slurry of silicon carbide. Initial grinding is done with 250-mesh grit. This is followed by 400-mesh grit and the finish lapping is carried out with 600-mesh grit. The lapping process may also be carried out mechanically on an iron lapping plate with 800-mesh Alundum.

The slices are washed in deionized water and are then air-dried before being etched in CP4 for three minutes. The acid etch is then followed by a second washing in deionized water and air-drying.

If the crystal has been grown by the vertical technique, three diameters, each of which is perpendicular to one of the major flats on the sides of the crystal, are lightly scribed across the face of the slice. One point is marked on each radius such that the six points describe a spiral from the center to the outer edge of the slice. Etch-pit counts are made at each of these points and at the center of the slice. Etch-pit counts on zone-levelled crystals are made by the same technique except that the points at which the counts are made are chosen arbitrarily.

Surface illumination is used with a projection microscope at a magnification of 100X. An area of  $1.0 \text{ mm}^2$  is counted at each of the seven points and the slice is scanned for the area of highest etch-pit density. Lineage, if present, is also detected during this scanning operation.

The average of the seven readings is reported as the "average etch-pit density" while the count obtained at the point of greatest density is reported as the maximum for the slice.

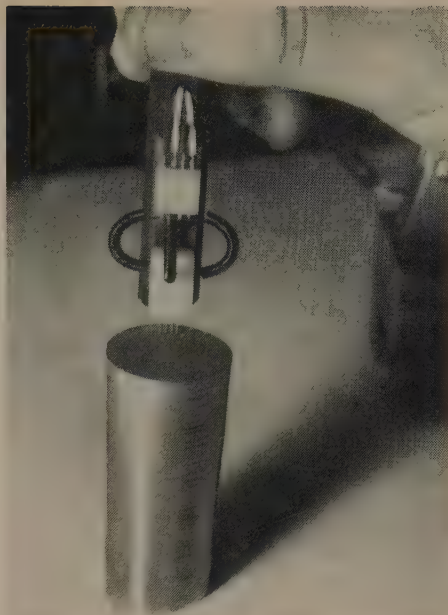
If the required maximum specification is expected, a piece about two-centimeters thick is cut from the crystal and the determination is repeated.

### Minority Carrier Lifetime in Germanium

Lifetimes of minority carriers are measured by the photoconductive-decay technique on the whole crystal.

The crystal is etched for two minutes in CP4, washed in deionized water, and air-dried. To permit the making of ohmic contacts, the ends of the crystal are abraded with 240-mesh silicon carbide. Care is taken during this operation to keep the etched surface of the crystal clean.

The crystal is clamped in a vice whose face plates are of plastic covered with copper braid which act as end contacts to the crystal. A battery and a large resistance are connected in series with the sample and the smallest possible current used.



The use of the four-point probe to determine the resistivity of the end of a germanium monocrystal. Care is taken to keep the probes at least six millimeters from the edge of the face.



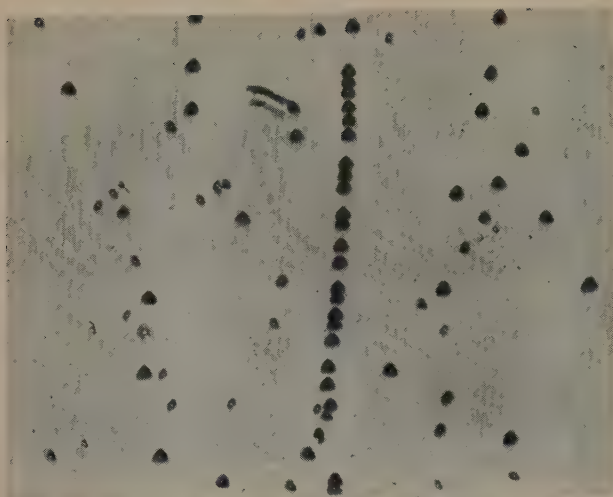
Germanium crystal showing the method used for determination of the points to be studied in etch-pit counting. For purposes of illustration the lines have been drawn heavily with a pencil. Normally, a tungsten or tungsten carbide scriber is used.

The light source used is a General Radio Strobolux and the decay curve is displayed on a Tektronix Oscilloscope, Model 535, equipped with a 53/54D amplifier. When low resistivity material is evaluated, the small signal necessitates the use of a Tektronix Type 122 Preamplifier.

The lifetime is determined as the decay constant,  $\tau$ , of the exponential decay curve,  $I = I_0 e^{-\frac{t}{\tau}}$ , where  $I_0$  is the height of the curve at time  $t_0$  and  $I$  is the height of the curve at time  $t$ .

Readings are also taken with the current reversed. If a significant difference is seen in the readings, the lifetime is suspect. A scan of the bar, taken with no bias current, should result in no signal on the oscilloscope. If a photovoltaic effect is seen, no reliable lifetime data can be obtained.

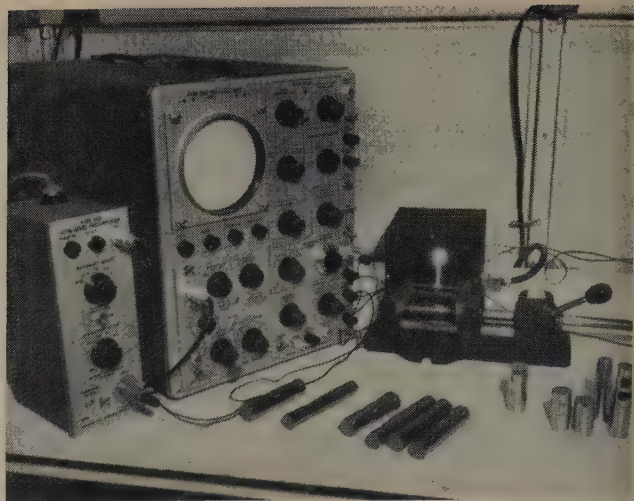




Photomicrograph of a piece of germanium monocrystal, cut on the  $\langle 111 \rangle$  plane and etched to reveal dislocation. The total area shown is about one square millimeter. The fine, continuous line is a reference mark made by a tungsten scriber. The aligned etch pits running through the center of the field are an example of lineage.

#### Minority Carrier Lifetime in Silicon

The techniques and apparatus used to determine the minority-carrier lifetime in silicon are exactly the same as those used for germanium with one exception: it is necessary to plate the ends of the silicon monocrystal with gold to permit a good ohmic contact to be made with the copper braid of the vise.



A minority-carrier-lifetime determination on a germanium monocrystal. The light source is contained in the black box in the background, and the bias voltage is applied to the crystal by a power supply which is not shown. The amplified signal from the crystal is displayed as an exponential curve on the oscilloscope.

#### Orientation—Silicon and Germanium

All monocrystals are grown from well oriented seeds which are carefully aligned in the chuck of the crystal puller. The orientation of the crystal is also checked after growth by either an optical or an x-ray technique.

## Introduction to Semiconductor Theory and Reverse Breakdown\*

C. A. ESCOFFERY, Ph.D.\*\*

### Part 3

#### Reverse Breakdown

For our present discussion, the most important region in the voltage-current characteristics of the silicon rectifier is that of high reverse bias, leading to *reverse breakdown* and its utilization in numerous devices and applications. It is beyond the scope of this article to present a detailed discussion of the breakdown mechanism, but an account of some of the present-day thoughts on the matter is desirable, to provide a better understanding of Zener diodes.

\*This is a reprint of an article which appeared in the "Zener Diode Handbook," published by International Rectifier Corp.

\*\*International Rectifier Corporation

Fig. 10 illustrates schematically the current-voltage relationships in a reverse-biased silicon diode. At low voltages, only a very small current flows, which, as we have seen, is due to the drift of thermally generated minority carriers. In an ideal diode, this current would saturate at a relatively low value, given by Eq. 17.

In practice, however, the current is not completely voltage-independent. The reasons for departure from the ideal case are attributed to surface effects, channels, inversion layers, and gross defects in the body of the junction.<sup>13-17</sup> Some recent data<sup>18</sup> appears to indicate that in silicon with short lifetime, bulk recombination centers are responsible for the large space-charge generated currents; as the lifetime is increased, however, the surface leakage currents become predominant.



Looking again at Fig. 10, we notice that as the reverse voltage is increased the leakage current remains essentially constant until a certain critical voltage, the *breakdown voltage*, is reached, at which point the current increases by many orders of magnitude. This is the breakdown region, and the current is known as the Zener current or the avalanche current, as explained further on below.

The breakdown point is of great interest not only in theory but also in practice, since the reverse voltage which can be imposed on rectifiers and other semiconductor devices is determined by it. In conventional diodes and rectifiers, it is desirable, if not mandatory, to operate considerably below the breakdown point; Zener or avalanche diodes, on the other hand, are designed to operate at the breakdown point.

### Zener Breakdown

Just what causes the very rapid rise in current at the breakdown point? For some time this question was an interesting and challenging one, but numerous experiments and theoretical analyses which have been made in recent years have added considerably to our knowledge of the mechanism of reverse breakdown.

Two types of breakdown have been considered, the Zener type and the avalanche type. In the early days of semiconductor device development it was believed<sup>19</sup> that the Zener mechanism was responsible for breakdown in germanium and silicon diodes. Devices, therefore, designed to utilize the breakdown phenomenon came to be known as Zener diodes. At the present, it is believed that both mechanisms may be operative, with the avalanche process being the predominant one, especially at reverse voltages above about six volts. Consequently, the term avalanche diode may be more appropriate but, rightly or wrongly, the designation Zener diode is likely to remain.

The Zener effect, so-called because it is based on a theory originally developed (for dielectrics) by C. Zener,<sup>20</sup> is actually a case of internal field emission. Under very intense fields (of the order of  $3 \times 10^5$  volts/cm), electrons can be made to traverse the forbidden energy gap by a process known as quantum-mechanical tunneling.\*

If the energy gap is likened unto a hill (potential barrier), classical mechanics tells us that electrons on one side of the hill cannot reach the other side unless they have sufficient energy to climb over the hill.

In the new, quantum mechanics such a limitation does not exist, however, and there is a statistical probability of finding electrons on the other side (Fig. 11). This probability,  $P$ , is given by an expression of the following type

$$\log P = \text{constant} \frac{E_g^{3/2}}{E} \quad (18)$$

\*This tunneling process appears to take place in the recently announced diodes developed by Esaki<sup>21</sup> and which have come to be known in this country as "tunnel diodes."

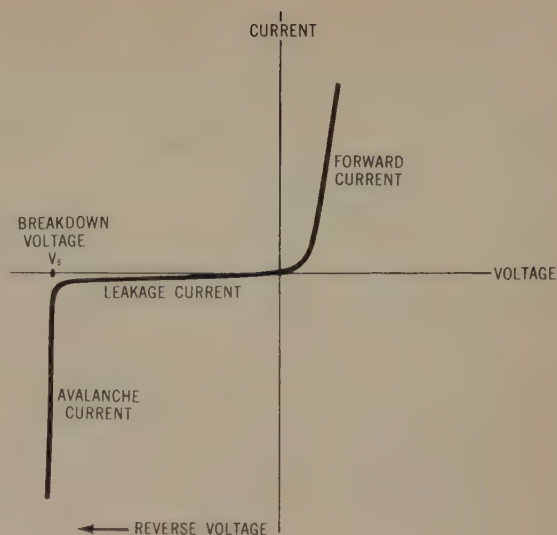


Fig. 10—Current-voltage characteristic of a typical  $p$ - $n$  junction.

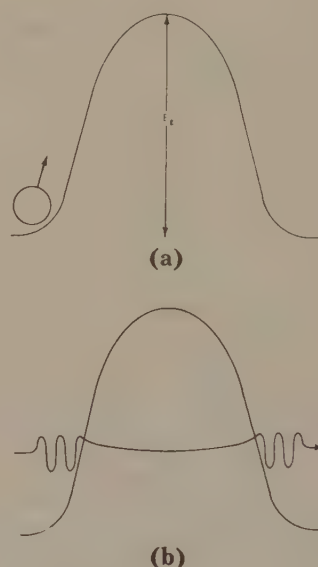


Fig. 11—(a) An electron with energy less than  $E_g$  cannot cross over the potential barrier, according to classical mechanics; (b) In quantum mechanics, the electron is considered as wave motion and there is a finite probability of it "tunneling" through the potential barrier.

where  $E_g$  is the energy gap and  $E$  is the applied field. When  $E$  is large, the probability approaches unity. Further calculations convert the probability into an actual current which is a function of the applied high electric field.

It is also possible to obtain equations relating the breakdown voltage to the resistivity of the semiconductor on each side of the junction.

In the case of abrupt silicon  $p$ - $n$  junctions, the Zener breakdown voltage is given by

$$V_s = 39\rho_n + 8\rho_p \quad (19)$$

where  $\rho_n$  and  $\rho_p$  are the resistivities in the  $n$  and  $p$  sides, respectively.



This equation, however, does not agree with experimental facts. For instance, Zener diodes made with 0.1 ohm-cm *n*-type silicon (*p*-side resistivity negligible) have a Zener voltage of about 15 volts instead of the 3.9 predicted by Eq. 19.

### Avalanche Breakdown

As experimental data appeared indicating lack of agreement with the Zener theory, doubts arose as to its validity in explaining breakdown in silicon and germanium diodes. The avalanche mechanism proposed by McKay<sup>22, 23</sup>, and elaborated by Wolff,<sup>24</sup> is now believed to be more in accord with the facts. It is similar to the process which occurs in an electrical discharge in gases, the theory of which was developed by Thompson.<sup>25</sup>

It will be recalled from our discussion of the reverse-biased *p-n* junction that the reverse current is due to the drift of minority carriers (holes in the *n*-side and electrons in the *p*-side) across the junction. In the avalanche process we visualize these carriers as being accelerated by the increasing voltage to higher and higher velocities. Eventually, they acquire sufficient energy\* to be able to strip off (ionize) bound valence electrons from the silicon atoms.

It should be noted that when an electron is knocked off from the parent atom a positive hole is automatically created. Every ionizing carrier (hole or electron)

\*The critical energy, or the "threshold for pair-production," by electrons in silicon is about 2.25 electron volts.<sup>26</sup> See also Refs. 24 and 28.

therefore creates *two* additional carriers. These new carriers are now, in turn, capable of being accelerated by the high field and of creating additional electron-hole pairs! One can readily see that this cumulative process is one of rapid multiplication of carriers, leading to a tremendously rapid increase in reverse current.

An important parameter in the avalanche theory is the *ionization coefficient*,  $\alpha$ , which can be considered as the number of ionizing collisions a given carrier makes in one cm. path length. In other words,  $\alpha$  is the number of electron-hole pairs created by a single carrier (electron or hole) as it travels one cm. under the applied electric field.

By means of suitable experiments and making certain assumptions (for instance, that  $\alpha$  is the same for electrons as for holes) it is possible to determine values of  $\alpha$  as a function of the applied field. This has been done<sup>22</sup> for different types of junctions, and the values obtained range from about 800 at an electric field strength of 200 kv/cm (across the *p-n* junction) to about 60,000 at a field strength of 500 kv/cm. Above these voltages, the ionization coefficient appears to saturate.

The actual determination of  $\alpha$  is done through measurements of the *multiplication ratio*,  $M$ , which is the ratio of the current leaving the junction to the current entering the junction. Multiplication, as we have seen, occurs even before we reach the breakdown voltage. By illuminating one side of the junction or bombarding it with alpha particles, one can inject carriers into it at voltages below the breakdown voltage and determine  $M$  from a study of the *V-I* characteristics.<sup>22</sup> A typical multiplication curve<sup>23</sup> is shown in Fig. 12.

It can be shown that the multiplication ratio  $M$  is related to the ionization coefficient  $\alpha$  by means of the following expression

$$1 - \frac{1}{M} = \int_0^w \alpha(E) dx \quad (20)$$

where  $w$  is the width of the barrier. Solutions to the above equation can be obtained for different types of junctions. Thus, for a silicon step junction (alloy type) one obtains

$$\alpha = 1.52 \times 10^{-7} N_I \frac{d \left( 1 - \frac{1}{M} \right)}{dE_m} \quad (21)$$

where  $E_m$  is the maximum field, and  $N_I$  is the net impurity density (donors minus acceptors).

Values of the parameter  $\alpha$  obtained from multiplication experiments agree quite well with those predicted theoretically according to the theory developed by Wolff.<sup>24</sup>

The above discussion assumed that  $\alpha$  was the same for both electrons and holes. Subsequent experiments have indicated that this is not actually the case,<sup>27-29</sup> and the mathematical analysis becomes more involved.

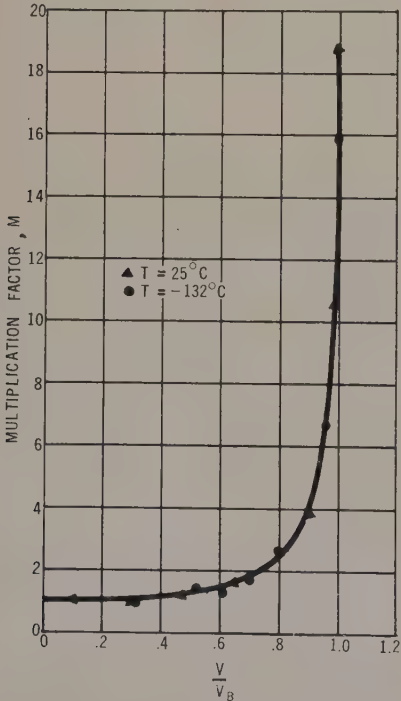


Fig. 12—Multiplication curves for a linear gradient junction with the voltage scale normalized to the breakdown voltage for different temperatures. (After McKay<sup>23</sup>).



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NPN PNP  
Medium Power  
High Voltage  
Drift



for:

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Neon Bulb Drivers  
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High Current Switches

Backed by 23 years of corporate integrity and unquestioned standards of quality and service. For switching devices to meet your needs, contact your nearest C. P. Clare & Co. sales office or C. P. CLARE TRANSISTOR CORPORATION, 260 GLEN HEAD ROAD, GLEN HEAD, L. I., NEW YORK.

Turn page for  
characteristics  
of **91** typical  
CLARE Transistors....



| TYPE              |                              | CHARACTERISTICS (25 ± 3°C) |                      |      |                         |                         |                         |                                    |      |      |                 |      | APPLICATION        |                    |                     |
|-------------------|------------------------------|----------------------------|----------------------|------|-------------------------|-------------------------|-------------------------|------------------------------------|------|------|-----------------|------|--------------------|--------------------|---------------------|
| TO-5 Case Outline | Max. Diss. (mW) 25°C Ambient | T <sub>j</sub> (°C)        | f <sub>ab</sub> (mc) |      | BV <sub>CBO</sub> (Vdc) | BV <sub>EBO</sub> (Vdc) | V <sub>RT</sub> * (Vdc) | h <sub>FE</sub>                    |      |      | h <sub>fe</sub> |      | SMALL SIGNAL AMPL. | LOW CURRENT SWITCH | HIGH CURRENT SWITCH |
|                   |                              | Max. Rated                 | Min.                 | Typ. | Min.                    | Min.                    | Min.                    | I <sub>C</sub> (mA <sub>dc</sub> ) | Min. | Max. | Min.            | Typ. |                    |                    |                     |
| 2N315A            | 150                          | 85                         | —                    | 5    | —25                     | —20                     | —25                     | —100                               | 20   | 50   | —               | 150  |                    | X                  |                     |
| 2N316A            | 150                          | 85                         | 8                    | 12   | —25                     | —20                     | —20                     | —200                               | 20   | 50   | —               | 150  |                    |                    | X                   |
| 2N317A            | 150                          | 85                         | 15                   | 20   | —20                     | —20                     | —15                     | —400                               | 20   | 60   | 100             | 200  |                    |                    | X                   |
| 2N395             | 150                          | 85                         | 3                    | 4.5  | —30                     | —20                     | —15                     | —10                                | 20   | —    |                 |      |                    | X                  |                     |
| 2N396             | 150                          | 85                         | 5                    | 8    | —30                     | —20                     | —20                     | —200                               | 15   | —    |                 |      |                    |                    | X                   |
| 2N397             | 150                          | 85                         | 10                   | 12   | —30                     | —20                     | —15                     | —200                               | 20   | —    |                 |      |                    |                    | X                   |
| 2N404             | 150                          | 100                        | 4                    | 12   | —25                     | —12                     | —24                     | —20                                | 40   | —    |                 |      |                    | X                  |                     |
| 2N413             | 150                          | 85                         | —                    | 2.5  | —30                     | —20                     |                         |                                    |      |      | —               | 30   | X                  |                    |                     |
| 2N414             | 170                          | 85                         | 3.5                  | 7    | —30                     | —20                     | —20                     | —20                                | 30   | —    | 40              | 80   | X                  | X                  |                     |
| 2N416             | 170                          | 85                         | 8                    | 10   | —30                     | —20                     | —15                     | —20                                | 40   | 250  | 60              | 100  | X                  | X                  |                     |
| 2N417             | 170                          | 85                         | 15                   | 20   | —30                     | —20                     | —15                     | —20                                | 60   | 180  | 80              | 150  | X                  | X                  |                     |
| 2N425             | 170                          | 85                         | 2.5                  | 4    | —30                     | —20                     | —                       | —100                               | 10   | —    |                 |      |                    | X                  |                     |
| 2N426             | 170                          | 85                         | 3                    | 6    | —30                     | —20                     | —                       | —100                               | 10   | —    |                 |      |                    | X                  |                     |
| 2N427             | 170                          | 85                         | 5                    | 11   | —30                     | —20                     | —22                     | —150                               | 15   | —    |                 |      |                    | X                  |                     |
| 2N428             | 170                          | 85                         | 10                   | 17   | —30                     | —20                     | —18                     | —200                               | 20   | —    |                 |      |                    |                    | X                   |
| 2N519A            | 150                          | 85                         | 0.5                  | —    | —20                     | —10                     | —20                     | —20                                | 20   | 50   | 15              | 25   | X                  | X                  |                     |
| 2N520A            | 150                          | 85                         | 3                    | —    | —20                     | —10                     | —20                     | —20                                | 40   | 170  | 40              | 100  | X                  | X                  |                     |
| 2N521A            | 150                          | 85                         | 8                    | —    | —20                     | —10                     | —18                     | —20                                | 60   | 250  | 70              | 150  | X                  | X                  |                     |
| 2N522A            | 150                          | 85                         | 15                   | —    | —20                     | —10                     | —15                     | —20                                | 80   | 320  | 100             | 200  | X                  | X                  |                     |
| 2N523A            | 150                          | 85                         | 21                   | —    | —20                     | —10                     | —10                     | —20                                | 100  | 400  | 125             | 300  | X                  | X                  |                     |
| 2N578             | 150                          | 85                         | 3                    | 5    | —20                     | —12                     | —15                     | —400                               | 10   | —    |                 |      |                    |                    | X                   |
| 2N579             | 150                          | 85                         | 5                    | 8    | —20                     | —12                     | —15                     | —400                               | 20   | —    |                 |      |                    |                    | X                   |
| 2N580             | 150                          | 85                         | 10                   | 15   | —20                     | —12                     | —15                     | —400                               | 30   | —    |                 |      |                    |                    | X                   |
| 2N581             | 150                          | 85                         | 4                    | 8    | —18                     | —10                     | —15                     | —20                                | 20   | —    |                 |      |                    | X                  |                     |
| 2N582             | 150                          | 85                         | 14                   | 18   | —25                     | —12                     | —15                     | —20                                | 40   | —    |                 |      |                    | X                  |                     |
| 2N658             | 170                          | 85                         | 2.5                  | 5    | —25                     | —12                     | —                       | —150                               | 15   | —    |                 |      |                    | X                  |                     |
| 2N659             | 170                          | 85                         | 5                    | 10   | —25                     | —12                     | —                       | —250                               | 25   | —    |                 |      |                    |                    | X                   |
| 2N660             | 170                          | 85                         | 10                   | 15   | —25                     | —12                     | —                       | —400                               | 40   | —    |                 |      |                    |                    | X                   |
| 2N661             | 170                          | 85                         | 15                   | 20   | —25                     | —12                     | —                       | —550                               | 55   | —    |                 |      |                    |                    | X                   |
| 2N662             | 170                          | 85                         | 4                    | 8    | —25                     | —12                     | —                       | —180                               | 18   | —    |                 |      |                    | X                  |                     |
| 2N1017            | 170                          | 85                         | 15                   | 20   | —30                     | —20                     | —                       | —200                               | 20   | —    |                 |      |                    |                    | X                   |
| 2N1018            | 170                          | 85                         | 20                   | 25   | —30                     | —20                     | —                       | —300                               | 30   | —    |                 |      |                    |                    | X                   |
| 2N1303            | 150                          | 85                         | 3                    | 4.5  | —25                     | —25                     | —25                     | —200                               | 10   | —    |                 |      |                    |                    | X                   |
| 2N1305            | 150                          | 85                         | 5                    | 8    | —25                     | —25                     | —20                     | —200                               | 15   | —    |                 |      |                    |                    | X                   |
| 2N1307            | 150                          | 85                         | 10                   | 12   | —25                     | —25                     | —15                     | —200                               | 20   | —    |                 |      |                    |                    | X                   |
| 2N1309            | 150                          | 85                         | 15                   | 20   | —25                     | —25                     | —15                     | —200                               | 20   | —    |                 |      |                    |                    | X                   |

## MEDIUM POWER GERMANIUM ALLOY

|         |     |     |     |    |     |     |     |      |    |     |  |  |  |  |   |
|---------|-----|-----|-----|----|-----|-----|-----|------|----|-----|--|--|--|--|---|
| 2N597** | 250 | 100 | 3   | 8  | —45 | —45 | —40 | —200 | 20 | —   |  |  |  |  | X |
| 2N598** | 250 | 100 | 6.5 | 10 | —35 | —30 | —35 | —200 | 50 | 160 |  |  |  |  | X |
| 2N599** | 250 | 100 | 12  | 18 | —30 | —20 | —20 | —200 | 75 | —   |  |  |  |  | X |

\*\*TO-9 Case Outline, collector internally connected to case.

## DIFFUSED BASE (DRIFT) GERMANIUM ALLOY

| TYPE                    |  | CHARACTERISTICS (25 ± 3°C) |  |      |                            |                            |                            |                 |      |      |      |                          | APPLICATION              |                           |                                       |
|-------------------------|--|----------------------------|--|------|----------------------------|----------------------------|----------------------------|-----------------|------|------|------|--------------------------|--------------------------|---------------------------|---------------------------------------|
| TO-5<br>Case<br>Outline | Max.<br>Diss.<br>(mW)<br>25°C<br>Ambient | T <sub>j</sub><br>(°C)     | f <sub>T</sub><br>Gain<br>Bandwidth<br>Product<br>(mc) |      | BV <sub>CBO</sub><br>(Vdc) | BV <sub>EBO</sub><br>(Vdc) | V <sub>RT</sub> *<br>(Vdc) | h <sub>FE</sub> |      |      |      | SMALL<br>SIGNAL<br>AMPL. | LOW<br>CURRENT<br>SWITCH | HIGH<br>CURRENT<br>SWITCH |                                       |
|                         |  |                            | Max.<br>Rated  | Min. |                            |                            |                            | Typ.            | Min. | Min. | Min. |                          |                          |                           | I <sub>B</sub><br>(mA <sub>dc</sub> ) |
| 2N602                   | 120                                      | 85                         | 10   | 20   | −20                        | −1                         | −20                        | −0.5            | —    | 20   | 80   |                          | X                        |                           |                                       |
| 2N603                   | 120                                      | 85                         | 30   | 40   | −30                        | −1                         | −20                        | −0.5            | —    | 30   | 100  |                          | X                        |                           |                                       |
| 2N604                   | 120                                      | 85                         | 50   | 60   | −30                        | −2                         | −30                        | −0.5            | —    | 40   | 140  |                          | X                        |                           |                                       |
| 2N643                   | 120                                      | 85                         | 20   | 30   | −30                        | −2                         | −29                        | —               | −5   | 20   | —    |                          | X                        |                           |                                       |
| 2N644                   | 120                                      | 85                         | 40   | 50   | −30                        | −2                         | −29                        | —               | −5   | 20   | —    |                          | X                        |                           |                                       |
| 2N645                   | 120                                      | 85                         | 60   | 75   | −30                        | −2                         | −29                        | —               | −5   | 20   | —    |                          | X                        |                           |                                       |
| 2N1065                  | 120                                      | 85                         | 10   | —    | −40                        | −1                         | −40                        | −0.5            | —    | 20   | 80   |                          | X                        |                           |                                       |
| 2N1450                  | 120                                      | 85                         | ***  |      | −30                        | −1                         | −20                        | —               | −10  | 20   | —    |                          | X                        |                           |                                       |

\*\*\*To switching specification.



**NPN****LOW VOLTAGE GERMANIUM ALLOY**

| TYPE                    |   | CHARACTERISTICS (25 ±3 °C)                  |                         |      |                            |                            |                            |                                       |      |      |                 |      |                          | APPLICATION              |                           |  |
|-------------------------|---|---|-------------------------|------|----------------------------|----------------------------|----------------------------|---------------------------------------|------|------|-----------------|------|--------------------------|--------------------------|---------------------------|--|
| TO-5<br>Case<br>Outline | Max.<br>Diss.<br>(mW)<br>25 °C<br>Ambient | T <sub>j</sub><br>(°C)<br><br>Max.<br>Rated | f <sub>ab</sub><br>(mc) |      | BV <sub>CBO</sub><br>(Vdc) | BV <sub>EBO</sub><br>(Vdc) | V <sub>RT</sub> *<br>(Vdc) | h <sub>FE</sub>                       |      |      | h <sub>fe</sub> |      | SMALL<br>SIGNAL<br>AMPL. | LOW<br>CURRENT<br>SWITCH | HIGH<br>CURRENT<br>SWITCH |  |
|                         |   |   | Min.                    | Typ. | Min.                       | Min.                       | Min.                       | I <sub>C</sub><br>(mA <sub>dc</sub> ) | Min. | Max. | Min.            | Typ. |                          |                          |                           |  |
| 2N356                   | 100                                       | 85  | —                       | 3    | +20                        | +20                        | +20                        | +100                                  | 20   | 50   |                 |      |                          | X                        |                           |  |
| 2N356A                  | 150                                       | 85  | —                       | 3    | +30                        | +20                        | +30                        | +100                                  | 20   | 50   |                 |      |                          | X                        |                           |  |
| 2N357                   | 100                                       | 85  | —                       | 6    | +20                        | +20                        | +18                        | +200                                  | 20   | 50   |                 |      |                          |                          | X                         |  |
| 2N357A                  | 150                                       | 85  | —                       | 6    | +30                        | +20                        | +30                        | +200                                  | 25   | 75   |                 |      |                          |                          | X                         |  |
| 2N358                   | 100                                       | 85  | —                       | 9    | +20                        | +20                        | +15                        | +300                                  | 20   | 50   |                 |      |                          |                          | X                         |  |
| 2N358A                  | 150                                       | 85  | —                       | 9    | +30                        | +20                        | +25                        | +300                                  | 25   | 75   |                 |      |                          |                          | X                         |  |
| 2N377                   | 150                                       | 100   | 2.5                     | 6    | +20                        | +15                        | —                          | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N377A                  | 150                                       | 100   | 2.5                     | 6    | +40                        | +15                        | —                          | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N385                   | 150                                       | 100   | 4                       | 6    | +25                        | +15                        | —                          | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N385A                  | 150                                       | 100   | 4                       | 6    | +40                        | +15                        | —                          | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N388                   | 150                                       | 100   | 5                       | 8    | +25                        | +15                        | —                          | +200                                  | 30   | —    |                 |      |                          |                          | X                         |  |
| 2N388A                  | 150                                       | 100   | 5                       | 8    | +40                        | +15                        | —                          | +200                                  | 30   | —    |                 |      |                          |                          | X                         |  |
| 2N438                   | 100                                       | 85  | 2.5                     | —    | +30                        | +25                        | —                          | +50                                   | 20   | —    | —               | 25   |                          | X                        |                           |  |
| 2N438A                  | 150                                       | 85  | 2.5                     | —    | +30                        | +25                        | —                          | +50                                   | 20   | —    | —               | 25   |                          | X                        |                           |  |
| 2N439                   | 100                                       | 85  | 5                       | —    | +30                        | +25                        | —                          | +50                                   | 30   | —    | —               | 35   |                          | X                        |                           |  |
| 2N439A                  | 150                                       | 85  | 5                       | —    | +30                        | +25                        | —                          | +50                                   | 30   | —    | —               | 35   |                          | X                        |                           |  |
| 2N440                   | 100                                       | 85  | 10                      | —    | +30                        | +25                        | —                          | +50                                   | 40   | —    | —               | 65   |                          | X                        |                           |  |
| 2N440A                  | 150                                       | 85  | 10                      | —    | +30                        | +25                        | —                          | +50                                   | 40   | —    | —               | 65   |                          | X                        |                           |  |
| 2N444A                  | 150                                       | 100   | 0.5                     | —    | +35                        | +10                        | +35                        | +20                                   | 20   | 40   | 15              | 25   | X                        | X                        |                           |  |
| 2N445A                  | 150                                       | 100   | 2                       | —    | +25                        | +10                        | +25                        | +20                                   | 40   | 160  | 35              | 70   | X                        | X                        |                           |  |
| 2N446A                  | 150                                       | 100   | 5                       | —    | +25                        | +10                        | +20                        | +20                                   | 60   | 250  | 60              | 120  | X                        | X                        |                           |  |
| 2N447A                  | 150                                       | 100   | 9                       | —    | +25                        | +10                        | +18                        | +20                                   | 80   | 300  | 85              | 150  | X                        | X                        |                           |  |
| 2N585                   | 150                                       | 85  | 3                       | 5    | +25                        | +20                        | +24                        | +20                                   | 20   | —    |                 |      |                          | X                        |                           |  |
| 2N587                   | 150                                       | 85  |                         |      | +40                        | +40                        | —                          | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N634                   | 150                                       | 85  | 5                       | 8    | +20                        | +15                        | +20                        | +200                                  | 15   | —    |                 |      |                          |                          | X                         |  |
| 2N635                   | 150                                       | 85  | 10                      | 12   | +20                        | +15                        | +20                        | +200                                  | 25   | —    |                 |      |                          |                          | X                         |  |
| 2N636                   | 150                                       | 85  | 15                      | 17   | +20                        | +15                        | +15                        | +200                                  | 35   | —    |                 |      |                          |                          | X                         |  |
| 2N679                   | 150                                       | 85  | 2                       | —    | +25                        | +15                        | —                          | +30                                   | 20   | —    |                 |      |                          | X                        |                           |  |
| 2N1000                  | 150                                       | 100   | 7                       | —    | +40                        | +40                        | +40                        | +100                                  | 25   | —    |                 |      |                          | X                        |                           |  |
| 2N1012                  | 150                                       | 100   | 3                       | —    | +40                        | +35                        | +45                        | +100                                  | 40   | —    |                 |      |                          | X                        |                           |  |
| 2N1090                  | 150                                       | 85  | 5                       | 7    | +25                        | +20                        | +18                        | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N1091                  | 150                                       | 85  | 10                      | 13   | +25                        | +20                        | +15                        | +200                                  | 30   | —    |                 |      |                          |                          | X                         |  |
| 2N1302                  | 150                                       | 85  | 3                       | 4.5  | +25                        | +25                        | +25                        | +200                                  | 10   | —    |                 |      |                          |                          | X                         |  |
| 2N1304                  | 150                                       | 85  | 5                       | 8    | +25                        | +25                        | +20                        | +200                                  | 15   | —    |                 |      |                          |                          | X                         |  |
| 2N1306                  | 150                                       | 85  | 10                      | 12   | +25                        | +25                        | +15                        | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N1308                  | 150                                       | 85  | 15                      | 20   | +25                        | +25                        | +15                        | +200                                  | 20   | —    |                 |      |                          |                          | X                         |  |
| 2N1605                  | 150                                       | 85  | 4                       | 12   | +25                        | +12                        | +24                        | +20                                   | 40   | —    |                 |      |                          | X                        |                           |  |

**PNP & NPN****HIGH VOLTAGE GERMANIUM ALLOY**

| TYPE                    | CHARACTERISTICS (25 ± 3 °C) |   |                        |                         |      |                            |                            |                            |                           |      |      | APPLICATION              |                          |                           |
|-------------------------|-----------------------------|---|------------------------|-------------------------|------|----------------------------|----------------------------|----------------------------|---------------------------|------|------|--------------------------|--------------------------|---------------------------|
| TO-5<br>Case<br>Outline | Polarity                    | Max.<br>Diss.<br>(mW)<br>25 °C<br>Ambient | T <sub>j</sub><br>(°C) | f <sub>ab</sub><br>(mc) |      | BV <sub>CBO</sub><br>(Vdc) | BV <sub>EBO</sub><br>(Vdc) | V <sub>RT</sub> *<br>(Vdc) | h <sub>FE</sub>           |      |      | SMALL<br>SIGNAL<br>AMPL. | LOW<br>CURRENT<br>SWITCH | HIGH<br>CURRENT<br>SWITCH |
|                         |                             |   | Max.<br>Rated          | Min.                    | Typ. | Min.                       | Min.                       | Min.                       | I <sub>C</sub><br>(mA dc) | Min. | Max. |                          |                          |                           |
| CP398                   | PNP                         | 150                                       | 85                     | —                       | 1    | —105                       | —50                        | —105                       | —5                        | 30   | —    |                          | X                        |                           |
| CP98                    | PNP                         | 150                                       | 85                     | 4                       | —    | —65                        | —55                        | —65                        | —30                       | 30   | —    |                          | X                        |                           |
| 2N398                   | PNP                         | 50  | 71                     | —                       | —    | —105                       | —50                        | —105                       | —5                        | 20   | —    |                          | X                        |                           |
| 2N1310                  | NPN                         | 120                                       | 85                     | —                       | 1    | +90                        | +20                        | +90                        | +5                        | 20   | —    |                          | X                        |                           |
| 2N1311                  | NPN                         | 120                                       | 85                     | —                       | 1.5  | +75                        | +20                        | +75                        | +5                        | 15   | —    |                          | X                        |                           |
| 2N1312                  | NPN                         | 120                                       | 85                     | —                       | 2    | +50                        | +20                        | +50                        | +20                       | 20   | —    |                          | X                        |                           |
| 2N1408                  | PNP                         | 150                                       | 85                     | —                       | —    | —50                        | —10                        | —50                        | —10                       | 10   | —    |                          | X                        |                           |

\*V<sub>RT</sub> (Reach Through Voltage) is measured by the floating emitter potential method.



**IN ADDITION TO NORMAL LOT SAMPLING QUALITY CONTROL AND INSPECTION PROCEDURES, CLARE PERFORMS THE FOLLOWING TESTS TO INSURE ABSOLUTE SPECIFICATION COMPLIANCE, HERMETIC SEAL RELIABILITY AND STABILITY OF CHARACTERISTICS.**



Clare transistors are 100 % tested for all specified minimum or maximum characteristics except dissipation which is tested on a sampling basis. Typical values are checked by sampling procedures.

As a hermetic seal test, Clare transistors are subjected to a 100 ppsi ethylene glycol test for a minimum of eight (8) hours on a 100 % basis before final testing.

To ensure stability of characteristics all Clare Transistors are aged for a minimum of 100 hours at  $\pm 100 \pm 2^\circ\text{C}$  before final testing.

The intent of this brief brochure is to present a broad outline of the transistors currently manufactured by Clare, with indication of important characteristics and general application for each type. An individual detailed specification for each type number is available from C. P. Clare Transistor Corporation or your local C. P. Clare & Company sales office.

#### **ALBUQUERQUE, N. M.**

R. E. McClendon Co.  
915 Yale Blvd., S.E.  
Albuquerque, N. M.  
CHapel 3-4551 (teletype AQ-266)

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Atlanta 10, Georgia  
Plaza 8-7496

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Needham 92, Massachusetts  
Hillcrest 4-4200

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Chicago 45, Illinois  
AM 2-7700, BR 4-3145

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Cincinnati 42, Ohio  
TWeed 1-3827

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Clearwater 3-7072

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ACademy 1-9030

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CHapel 4-5485 (Dayton)

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JACKSON 8-3811

#### **KANSAS CITY, KANSAS**

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Mission, Kansas (RA 2-2441)

#### **LOS ANGELES, CALIF.**

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Los Angeles 28, Calif.  
HOLlywood 2-7209

#### **MINNEAPOLIS, MINN.**

C. P. Clare & Co.  
P.O. Box 6103—Edina Branch  
Minneapolis 24, Minn.  
TAYlor 4-7064

#### **NEW YORK, NEW YORK**

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MUrray Hill 4-1702

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Orlando, Florida  
GARDen 5-3083

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Interesting is the fact that in silicon the ionization coefficient for electrons is larger than for holes, whereas in germanium the opposite is true.

By using more refined methods for measuring the multiplication as a function of bias, Chynoweth<sup>26, 29</sup> discovered that  $\alpha$  can be expressed quite simply as an exponential function of the field,  $E$ , or

$$\alpha = a \exp\left(-\frac{b}{E}\right) \quad (22)$$

where  $a$  and  $b$  are constants. Since the above equation is not indicated by Wolff's theory,<sup>24</sup> it is suggested that a fresh theoretical approach is necessary. Quite recently, Maserjian<sup>40</sup> has assumed the above exponential dependence for  $\alpha$  to be general and has derived expressions which predict avalanche breakdown for most  $p$ - $n$  structures.

In alloyed type diodes, the breakdown voltage,  $V_B$ , can be adjusted by control of the resistivity (net impurity density). For a given resistivity,  $n$ -type silicon and germanium break down at a higher voltage than  $p$ -type. This is due to the fact that in these materials the electron mobility is greater than the hole mobility. In  $p$ -material the minority carrier current is by electrons and  $V_B$  will not have to be as high to reach avalanche conditions.

Although the avalanche theory is believed to be the predominant process, there is evidence that the Zener mechanism occurs at low voltages and in thin junctions.<sup>22, 31</sup> In silicon diodes with breakdown voltage below about six volts, the breakdown point decreases with rise in temperature. This negative temperature coefficient is consistent with the decrease of the forbidden energy gap with temperature and a consequent lower Zener field.

On the other hand, silicon junctions with breakdown above about six volts have a positive temperature coefficient, because the mobility of the carriers decreases with rise in temperature and higher voltages are required to produce ionization by collision.

Although theory would predict a "sharp" breakdown, in practice one often finds a rounding of the current-voltage characteristics, or what is known as a "soft" breakdown or a "soft knee," particularly at low voltages. The causative factors are not yet completely understood, but they have been ascribed to surface conditions, bulk effects,<sup>32</sup> and thermal effects.<sup>33</sup>

It has also been suggested that the effect of temperature rise due to current flow must be considered in order to explain the shape of the  $V$ - $I$  curve in the avalanche region.<sup>34</sup> In addition, the  $V$ - $I$  curve itself is not smooth but has a number of discontinuities, which are believed due to the existence of localized breakdown regions, called *microplasmas*.<sup>37</sup>

Apparently, the actual breakdown occurs only in isolated discrete spots, where the current density is obviously very high. The emission of visible light has been observed<sup>35-37</sup> in diodes operating in the avalanche region, and it is believed that the light originates in

these spots which may be due to dislocations.<sup>38</sup> The effect is best observed in silicon solar cells, where the junction lies parallel and very close to the surface. Photons with energy as high as 3.2 electron volts (blue light) have been detected.

The spectrum of the light emitted by junctions in which avalanche is taking place indicates that two concurrent mechanisms are probably responsible for the light emission:<sup>38</sup> (a) *de-excitation radiation*—where carriers lose energy (and emit photons with energies up to the threshold value of 2.3 eV), but remain within the same energy band; (b) *recombination radiation*—where highly energetic electrons in the conduction band drop into the valence band and recombine with a hole (emitting photons of energies above 1.1 eV, the energy gap of silicon). Fig. 13 is a schematic representation of the two processes.<sup>39</sup>

Considerable research is still going on pertaining to the fascinating and important phenomenon of reverse breakdown. These efforts are leading to a greater understanding of the behavior of electrons and holes in semiconductors, and to the design and development of improved semiconductor devices.

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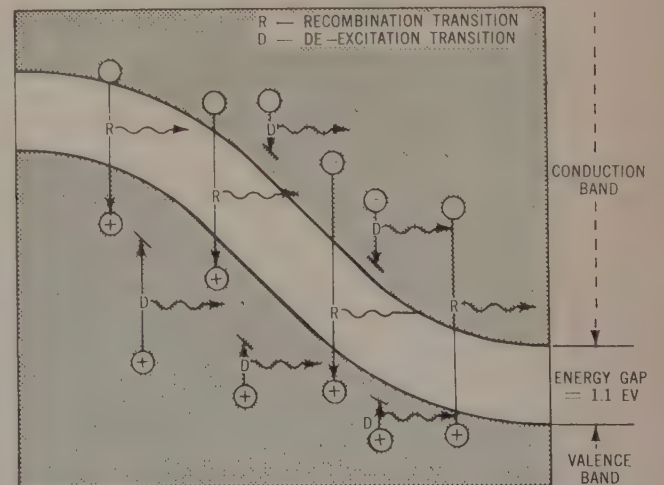


Fig. 13—Schematic representation of the two types of processes responsible for light emission. (After Chynoweth<sup>39</sup>).



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# Transistor Switching Analysis

Dr. C. A. MEAD\*

## Part 2

**Diode Recovery.** Suppose we connect a junction diode in the circuit shown in Fig. 6. If the applied voltage  $V$  remains at  $+V_1$  for a sufficient time, the current  $i$  will reach a steady state value very nearly  $V_1/R$ , assuming the forward voltage drop across the diode is small compared with circuit voltages. If now

the applied voltage is abruptly changed to  $-V_2$ , the current is observed to assume a nearly constant value  $-V_2/R$  for a storage time  $t_s$ , after which it decays rapidly to its small steady state reverse value  $i_s$ . The explanation for this action is as follows: <sup>(5)</sup>

At  $t = 0$ , the excess density of minority carriers near the junction is as shown by the top curve of Fig. 7. At a slightly later time, the applied voltage

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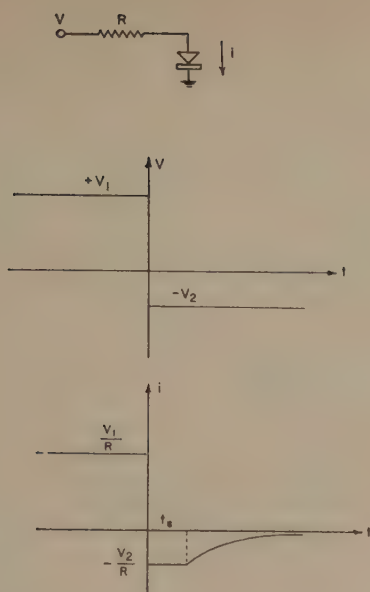


Fig. 6—Recovery of p-n diode from step input.

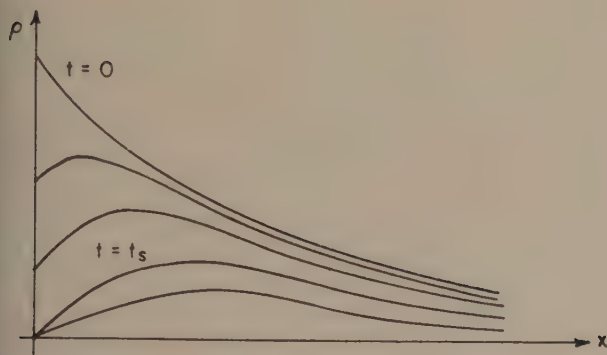


Fig. 7—Excess density distribution in p-n diode during recovery.

has reversed, but the stored carriers have not had time to recombine or diffuse away. The rate at which they may cross the junction is limited to a maximum reverse current of  $V_2/R$ , since a higher value would appreciably forward bias the junction and hence be self-annihilating. However, since the excess density of minority carriers at the junction is greater than zero, the junction must remain slightly forward biased, and the voltage across the junction remains small. As long as the junction remains forward biased, the current is determined by the external circuit. In this case, the current during the storage period is very nearly  $-V_2/R$ . This condition determines the slope of minority carrier density at the junction, which is proportional to the junction current. At the end of the storage time  $t_s$ , the junction excess density has just reached zero and approaches  $-p_n$  as the junction becomes reverse biased. Since the junction excess density is essentially constant (nearly zero) for any reverse bias voltage, the current is no longer af-

ected by the junction voltage but is determined only by the conditions within the semiconductor. Therefore, the decay time is characterized by the minority carrier lifetime.

**Diode Storage Time Calculation.** We may obtain a good estimate of the recovery time from a simple calculation using the one section lumped model of Fig. 5c. Although the results are not nearly as accurate as those which will shortly be obtained for the transistor, they are significant and the method used is typical of all lumped model calculations.

#### (a) Steady State

Since the diode is forward biased, the voltage across it is small compared with  $V_1$  and we may assume

$$\frac{V_1}{R} \approx I = G\rho_{ss}$$

The voltage across the diode may be found by using the value of  $\rho_{ss}$  obtained from this equation and the exponential junction law.

#### (b) Storage Period

When the applied voltage changes sign, the charge on  $C$  cannot change instantaneously, and hence  $\rho$  must be continuous. As long as  $\rho$  is greater than zero, the diode is forward biased and the voltage across it is small. Hence the current is very nearly  $-V_2/R$ . To determine the storage time  $t_s$ , we find  $\rho$  as a function of time assuming the current remains at  $-V_2/R$ . Then, when  $\rho$  becomes very nearly zero, the junction voltage may assume any negative value, and the current approaches zero. To obtain the complete solution for  $\rho$  as a function of time, we superpose the steady state value upon the response to a negative current step of magnitude  $(V_1 + V_2)/R$ , with the result

$$\rho G = \frac{V_1}{R} - \frac{V_1 + V_2}{R} (1 - e^{-\omega_h t})$$

At  $t = t_s$ , the excess density has just reached zero.

$$t_s = \frac{1}{\omega_h} \ln \left( \frac{V_1 + V_2}{V_2} \right) \quad (4)$$

Since there is no longer any charge on  $C$ , the current will abruptly stop at  $t = t_s$ , according to the lumped model. In reality, we know it dies away smoothly. Hence, in this particular case, the lumped model has predicted zero decay time, which may be explained as follows: Since we have used only one lumped section, we have not included the effect of carriers at some distance from the junction, and it is just these carriers which diffuse back to the junction and cause the exponential type decay. With any finite number of lumped sections, the calculated current will exhibit a discontinuity since  $\rho$  at the junction approaches zero with a finite  $d\rho/dt$ , and causes current through the capacitor nearest the junction which must abruptly cease as  $\rho$  is clamped at  $-p_n$ . This lack of accuracy was introduced because of our attempt to use one lumped section to approximate too large a region of



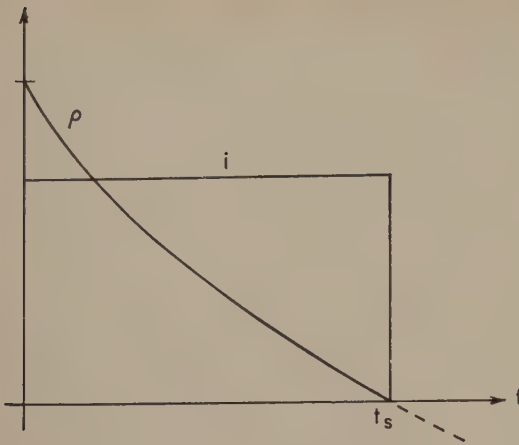


Fig. 8—Recovery characteristic predicted by simple single section model.

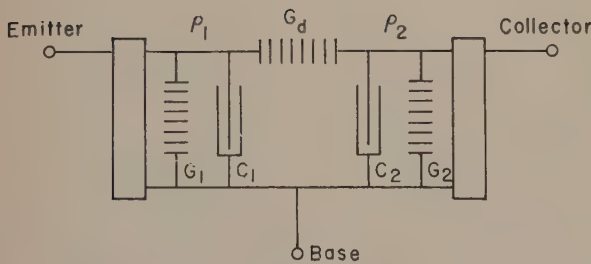


Fig. 9—Complete two-section lumped model of junction transistor with high conductivity collector and emitter regions.

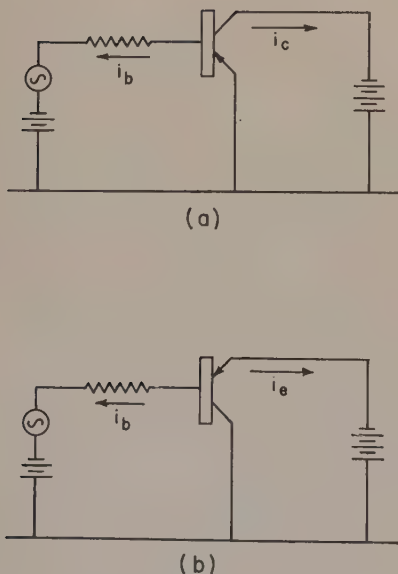


Fig. 10—*p-n-p* transistor in (a) normal and (b) inverse connection.

the semiconductor. The problem is especially bad in fast diodes since the lifetime is made very short and consequently the region to be represented by the lumped model is normally many diffusion lengths. On the other hand, in a transistor the base region is only a very small fraction of a diffusion length and the accuracy obtained is very much better. The justification for using the single section diode model is the ease of determining the element values. In practical design work the choice is usually not between a simple or elegant analysis but rather between a simple analysis or none at all.

### Transistor Lumped Model

If the transistor emitter and collector conductivities are high compared to the base conductivity, we may neglect any carrier injection into the emitter and collector and consider only minority carriers in the base region. A two-section model results as shown in Fig. 9. In this figure  $\rho_1$  represents the excess density near the emitter, given by

$$\rho_1 = p_n (e^{q v_{eb}/kT} - 1)$$

where  $v_{eb}$  is the emitter-base junction voltage;  $C_1$  and  $G_1$  represent storage and recombination near the emitter,  $G_d$  represents diffusion from emitter to collector,  $\rho_2$  is the excess density near the collector, given by

$$\rho_2 = p_n (e^{q v_{cb}/kT} - 1)$$

where  $v_{cb}$  is the collector-base junction voltage;  $C_2$  and  $G_2$  represent storage and recombination near the collector. Both voltages are taken positive when the junction is forward biased.

When the transistor is normally biased as shown in Fig. 10a,  $\rho_2 = -p_n = \text{constant}$  and thus no *a-c* current flows through  $G_2$  or  $C_2$ . Therefore, the *a-c* collector current

$$i_c = \rho_1 G_d$$

and the *a-c* base current

$$i_b = \rho_1 (G_1 + sC_1)$$

using the Laplace transform notation. Hence

$$\frac{i_c}{i_b} = \frac{G_d}{G_1 + sC_1} = \frac{G_d/G_1}{1 + s \frac{C_1}{G_1}} = \frac{\beta}{1 + \frac{s}{\omega_\beta}}$$

where  $\beta$  is the low frequency, short circuit, common emitter, current gain and  $\omega_\beta$  is the short circuit, common emitter current gain cutoff frequency. Thus

$$\beta = \frac{G_d}{G_1}$$

$$\omega_\beta = \frac{G_1}{C_1}$$

Since for all reasonable transistors  $\beta \gg 1$ , in all cases of interest  $G_d \gg G_1$ . If the transistor is inverted, i.e., the collector forward biased (acting as an



emitter) and the emitter reverse biased (acting as a collector) as shown in Fig. 10b,  $\rho_1 = -p_n = \text{constant}$  and no  $a$ -c current flows through  $G_1$  or  $C_1$ .

The  $a$ -c emitter current

$$i_e = \rho_2 G_d$$

and the base current

$$i_b = \rho_2 (G_2 + C_2 s).$$

Hence

$$\frac{i_e}{i_b} = \frac{G_d}{G_2 + C_2 s} = \frac{G_d/G_2}{1 + s \frac{C_2}{G_2}} = \frac{\beta_i}{1 + \frac{s}{\omega_{\beta i}}}$$

where  $\beta_i$  is the inverted current gain and  $\omega_{\beta i}$  is the inverted cutoff frequency. Thus

$$\beta_i = \frac{G_d}{G_2}$$

$$\omega_{\beta i} = \frac{G_2}{C_2}$$

Since  $\beta_i$  is often quite small, we may make no statement with regard to the relative magnitude of  $G_2$  and  $G_d$ .

By the four simple measurements of  $\beta$ ,  $\beta_i$ ,  $\omega_\beta$  and  $\omega_{\beta i}$ , we are able to determine all of the input elements in terms of one (preferably  $G_d$ ). For many calculations we need not proceed further. However, if we are interested in the voltage across a forward biased junction, we need to determine  $p_n G_d$ . As in the case of the diode, we cannot determine either  $p_n$  or  $G_d$  separately by external measurements. Perhaps the best method of determining  $p_n G_d$  is to measure the  $d$ -c emitter-base voltage  $v_{eb}$  and the  $d$ -c collector current  $I_c$  in the normal bias connection.

$$I_c = (\rho_1 + \rho_n) G_d = p_n G_d e^{qv_{eb}/kT}$$

$$p_n G_d = I_c e^{-qv_{eb}/kT} \quad (5)$$

For germanium transistors it is also possible to obtain an approximate value of  $p_n G_d$  from a measurement of  $i_{co}$ , the collector cutoff current when the emitter is open circuited.

$$i_{co} = p_n \left( G_2 + \frac{G_1 G_d}{G_1 + G_d} \right) = p_n G_d \left( \frac{1}{\beta_i} + \frac{1}{1 + \beta} \right)$$

$$\approx p_n G_d \left( \frac{1}{\beta_i} + \frac{1}{\beta} \right)$$

hence

$$p_n G_d \approx \frac{i_{co} \beta \beta_i}{\beta + \beta_i} \quad (6)$$

However,  $i_{co}$  is normally composed of a certain amount of surface leakage current and junction depletion layer generation current. Hence the value of  $p_n G_d$  obtained in this way may be considerably in error. A measurement of  $v_{eb}$  and  $i_c$  at a bias current

large compared to  $i_{co}$  is much to be preferred. In silicon units the  $i_{co}$  is largely determined by carrier generation within the junction depletion region and therefore should never be used in the determination of  $p_n G_d$ .

**Transistor Small Signal Performance.** We have already used the common emitter current gain characteristic of the transistor in order to determine the values of the lumped model elements. It is of interest to investigate the other aspects of small signal performance as predicted by the lumped model. If the transistor is used in the common base connection and normally biased, the  $a$ -c collector current

$$i_c = \rho_1 G_d$$

and the  $a$ -c emitter current

$$i_e = \rho_1 (G_d + G_1 + C_1 s)$$

Therefore

$$\frac{i_c}{i_e} = \frac{G_d}{G_d + G_1 + C_1 s} = \frac{\frac{G_d}{G_d + G_1}}{1 + \frac{C_1}{G_d + G_1} s} = \frac{\alpha}{1 + \frac{s}{\omega_\alpha}}$$

where

$$\alpha = \frac{G_d}{G_d + G_1} = \frac{\beta}{1 + \beta}$$

$$\omega_\alpha = \frac{G_d + G_1}{C_1} = (1 + \beta) \omega_\beta$$

Thus the lumped model gives the single time constant approximation for the current gain which is quite accurate for operation well below the alpha cutoff frequency and is commonly used for high frequency calculations. If  $\beta \gg 1$ , we may simplify the last expression as follows:

$$\omega_\alpha \approx \frac{G_d}{C_1} = \beta \omega_\beta$$

In the inverse common base connection similar expressions apply.

$$i_e = \rho_2 G_d$$

$$i_c = \rho_2 (G_d + G_2 + C_2 s)$$

$$\frac{i_c}{i_e} = \frac{G_d}{G_d + G_2 + C_2 s} = \frac{\frac{G_d}{G_d + G_2}}{1 + \frac{C_2}{G_d + G_2} s} = \frac{\alpha_i}{1 + \frac{s}{\omega_{\alpha i}}}$$

$$\alpha_i = \frac{G_d}{G_d + G_2} = \frac{\beta_i}{1 + \beta_i}$$

$$\omega_{\alpha i} = \frac{G_d + G_2}{C_1} = (1 + \beta_i) \omega_{\beta i}$$

where  $\beta_i$  is not necessarily large compared to unity.



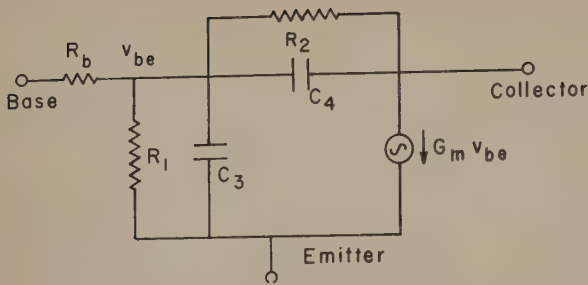


Fig. 11—Transistor small signal equivalent circuit as developed from lumped model.

We may now ask what type of complete common emitter, small signal equivalent circuit results from the lumped model. For small signals, the emitter *a-c* minority carrier density is proportional to the *a-c* emitter-base voltage as shown in equation 3.

$$\rho_1 = \frac{q}{kT} \rho_o v_{be} = K_1 v_{be}$$

The effective *a-c* density at the collector is also proportional to the *a-c* collector-base voltage, due to collector depletion layer widening or Early effect.<sup>(2), (6)</sup>

$$\rho_2 = K_2 v_{cb} \quad K_2 \ll K_1$$

where all quantities of interest are now *a-c* components.

In the common emitter connection, expressions for the base and collector currents become

$$i_c = -\rho_1 G_d + \rho_2 (G_d + G_2 + C_2 s)$$

$$i_b = \rho_1 (G_1 + C_1 s) + \rho_2 (G_2 + C_2 s)$$

Since the emitter voltage is taken as zero, we may rewrite the currents in terms of collector and base voltages.

$$i_c = v_{be} [-K_1 G_d + K_2 (G_d + G_2 + C_2 s)] - K_2 (G_d + G_2 + C_2 s) v_c$$

$$i_b = -v_{be} [K_1 (G_1 + C_1 s) - K_2 (G_2 + C_2 s)] + K_2 (G_2 + C_2 s) v_c$$

These equations correspond to the circuit shown in Fig. 11, where

$$R_1 = \frac{1}{K_1 G_1}$$

$$R_2 = \frac{1}{K_2 G_2}$$

$$C_3 = K_1 C_1$$

$$C_4 = K_2 C_2$$

$$g_m = K_1 G_d$$

The extrinsic base resistance  $R_b$  must be added in series with the base terminal as shown. This circuit is similar to that proposed by Giacoletto<sup>(7)</sup> and widely used for high frequency work. Thus, the lumped model reduces simply to a quite accurate representation in this special case, yet is much more general in that it is useful for all transistor operating conditions.

(To be continued)

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### APPLICATIONS ENGINEERING DIGEST NO. 50

(Circle 198 on Reader Service Card)

#### Gallium-Arsenide Tunnel Diode Scaler;

Philco Corp., Philadelphia, Pa.

Development of high-speed scalers using gallium-arsenide tunnel diodes in series was announced by the Research Division of Philco Corporation. With double-pulse resolution for switching between intermediate states of less than 14 nanoseconds, the device utilizes the characteristic of series-connected tunnel diodes wherein voltage is a multi-valued function of current.

Upon initial application of source current, the stack of diodes—treated

as a two-terminal device regardless of the number of diodes—maintains its lowest voltage. Each pulse of proper amplitude applied to the input terminal boosts stack voltage to the next higher level. The transistor reset circuit is biased to operate when the highest stack level is reached. See Figs. 50.1 and 50.2.

Utilization of GaAs tunnel diodes was encouraged through the devices' in-

trinsically higher voltage swings, their peak-to-valley ratios of greater than ten to one, and switching times of less than a nanosecond.

With the tunnel-diode scaler, extremely high switching and reset speeds are supplemented by significant reduction in space, weight and power requirements in comparison with beam-switching tubes or cascaded transistor binaries used in like applications.

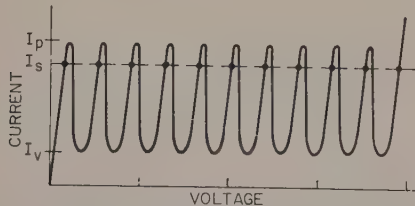


Fig. 50.1—V-I characteristic of tunnel diodes in series.

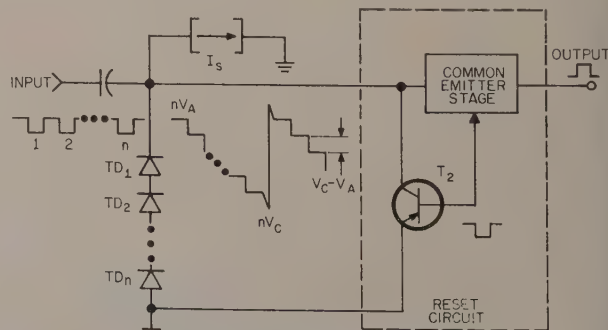


Fig. 50.2—Tunnel diode scaler circuit diagram.



## Novel Trigistor Circuit Combines Low Level Logic Element and High Level Switch; Solid State Products Inc., Salem, Mass.

The versatility of the Trigistor as a static switching element is graphically illustrated in the circuit of Fig. 51.1. In this configuration the Trigistor performs a dual function as a low-level logic element and a high-level static switch. Once it has been turned on, a Trigistor will carry whatever current the load dictates—within its power dissipation ratings—and such a parallel role becomes strikingly practical. Loads such as print-hammers, solenoids, magnetic clutches and brakes, relays, etc. are generally well within the current handling ability of the Trigistor. In this illustration, the Trigistor has two separate loads. Assume, for the moment, that diode  $D_1$  and the high power load are disconnected. The balance of the circuit could represent a portion of a logic circuit, such as a shift register or binary counter stage. When the Trigistor is "on", it carries

a collector current of 4 ma through  $R_L$ . At this level, it can easily be turned off by means of a negative pulse applied to the base terminal. When the Trigistor is "off", its collector voltage is equal to the collector d-c supply voltage.  $D_1$  will continue to block, provided the d-c supply voltage is greater than the peak positive a-c voltage. However, if the Trigistor happens to be "on" as a result of logic operations, it and  $D_1$  will conduct current to the high power load. During this period of high current flow, the Trigistor cannot be turned off, so that logic functions and high level output func-

tions must be accomplished on a time-sharing basis. During each negative half cycle, one or hundreds of logic operations can be performed. At the conclusion of a sequence of logic operations, "read-out" is obtained by applying a positive voltage pulse to the bus connected to the power loads.

Pulse power can be used instead of a-c to operate high power loads, well up into the ampere region.

(Circle 199 on Reader Service Card)

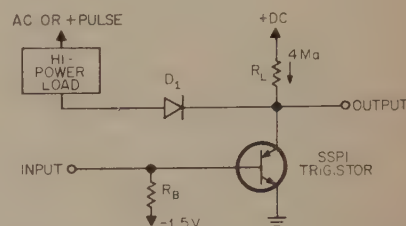


Fig. 51.1—Trigistor dual function circuit.

# APPLICATIONS ENGINEERING DIGEST NO. 52

## High Peak Operation and Choice of Collector Supply Voltages for Core-Transistor Circuits; Fairchild Semiconductor Corp., Mountain View, Calif. (I. Haas and R. T. Kikoshima)

### Circuit Conditions

Shown in Fig. 52.1 is a typical core-transistor logic circuit. When Core 1 is switched and the voltage across  $W_0$  is such that the transistor  $Q_1$  is turned on, the collector current through  $W_1$  may or may not switch Core 2, depending on the direction of the net mmf applied to the core and the state of Core 2 before the application of the pulse in Core 1. In either case, a voltage is developed across  $W_1$  when the transistor is going from "on" to "off" which adds to the collector supply  $V_{CC}$ . This voltage is proportional to the reversible flux-mmf characteristics of the core and the time rate of change of collector current.

In some systems of core transistor logic, one transistor may drive many cores. The transient voltages developed in the winding during "turn-off" are additive and it is possible, under this condition, to drive the transistor into the avalanche mode.

### Choice of the Collector Supply Voltages

The factors determining the maximum allowable collector supply voltage for a core transistor circuit are:

1. The minimum  $LV_{CER}$  as specified by the data sheet.
2. The minimum  $BV_{CBO}$ .

(Circle 200 on Reader Service Card)

The limit established by the minimum  $LV_{CER}$  rating is due to the fact that a higher value of  $V_{CC}$  would result in a bistable circuit with extremely high dissipation in the avalanche mode. It has been shown that clipping due to  $LV_{CER}$  is permissible under certain conditions.

The second limit arises from the condition shown in Fig. 52.2. Under this condition, the cores in the collector circuit of an "off" transistor are being switched to the opposite state by the other transistors. In the worst case, all the cores are switched and the voltage across all the windings is  $NV_{peak}$  (where  $V_{peak}$  is the peak voltage developed across one core winding and  $N$  is the total number of cores). This voltage ( $NV_{peak}$ ) added to the collector supply voltage must be less than  $BV_{CBO}$ .

Thus, the collector supply voltage can be as large as  $LV_{CER}$  from the point of view of stable operation. However, a lower value might be desirable in applications as described in the preceding paragraph. The worst case design for this application must be such that the collector to emitter voltage is never greater than  $BV_{CBO}$ . If this condition is not met, the collector current flowing in transistor  $Q_1$  due to the breakdown will load  $Q_2$ ,  $Q_3$ , etc., and impair the switching times and prevent full switching of the cores.

To demonstrate the operation of the circuit with collector supply voltages approaching  $LV_{CER}$ , the circuit in Fig. 52.3 was investigated.

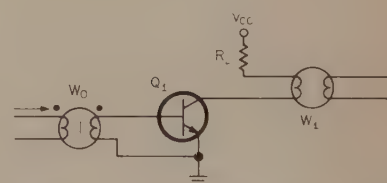


Fig. 52.1—Core-Transistor logic circuit.

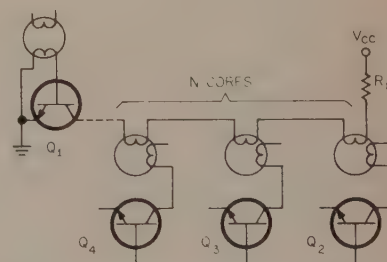


Fig. 52.2—Typical core-transistor logic configuration.

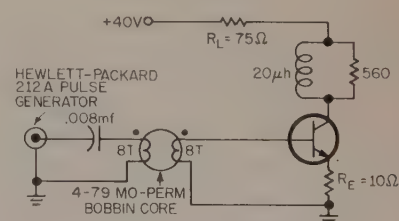


Fig. 52.3—Test circuit.



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| Research in the Preparation of Hyperpure Single Crystal Silicon Carbide   | Tech Abst Bul ASTIA<br>Apr 1 1960 (Uncl)<br>(To obtain see item 1)                    | Extensive experiments were carried out on the preparation of single crystal SiC in a graphite tube furnace, after the method of Lely.  | D. R. Hamilton                                     |
| A Study of the Piezoresistive Effects and Preparation Techniques of the Oxide Semiconductor Rutile                    | Tech Abst Bul ASTIA<br>Apr 1 1960 (Uncl)<br>(To obtain see item 1)                    | The fourth rank piezoresistive tensor for the D <sub>4h</sub> tetragonal symmetry of rutile may be expressed in terms of seven piezoresistive coefficients.  | L. E. Hollander, Jr.<br>T. J. Diesel<br>G. L. Vick |
| Research and Development for 70-Ampere High Power Silicon Controlled Rectifier  | Tech Abst Bul ASTIA<br>Apr 1 1960 (Uncl)<br>(To obtain see item 1)                    | Improved electrical characteristics continue to be achieved with the 1/2 in. diam. junction. Etch cutting of pellets showed improved yield over ultrasonic cutting followed by edge etching.   | G. N. Hall<br>R. P. Lyon                           |
| Investigation of Methods for Measuring the Equivalent Electrical Parameters of Quartz Crystals                        | U.S. Govt Res Repts<br>April 15, 1960<br>LC \$12.30 PB138495                          | A prototype thermistor-bridge power meter for measuring the <i>r-f</i> power dissipated in VHF quartz crystals was constructed and tested.   | D. W. Robertson<br>S. N. Witt, Jr.<br>W. R. Free   |
| Transistorized Relay Amplifier  | U.S. Govt Res Repts<br>April 15 1960<br>LC \$3.30 PB144715                            | The development of a transistorized relay amplifier of superior performance to vacuum-tube type fo amplifiers is described.  | R. A. Bruns<br>J. H. Wilcher                       |



# PATENT REVIEW\*

## Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from June 10, 1958 to July 15, 1958. In subsequent issues, patents issued from July 15, 1958 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

June 10, 1958

2,838,686 Amplifier For Pulse Type Signals—J. P. Eckert, Jr. Assignee: Sperry Rand Corporation. A pulse amplifier in which the input is controlled so that in response to each input the amplifier builds up to maximum output and remains there until cutoff by a clock pulse.

2,838,690 Push-Pull Transistor Circuits—J. P. Eckert, Jr., H. J. Gray, Jr. Assignee: Sperry Rand Corporation. A transistor circuit that permits multilayer logic to be performed at high repetition rates with a large number of possible drives.

June 17, 1958

2,839,436 Method and Apparatus for Growing Semiconductor Crystals—B. Cornelson Assignee: Texas Instruments Incorporated. A method for supplying heat to a semiconductor melt in which a crystal is growing, in order to insure a plane solid liquid interface between the crystal and the melt during the growing operation.

2,839,620 Transistor Amplifier Circuits—F. D. Waldhauer. Assignee: R.C.A. A push-pull signal amplifier using opposite conductivity type transistors to insure balanced operation without requiring a balanced driving source.

2,839,645 Photocell Structure—F. A. Hester Assignee: Clairex Corporation. A radiation detecting photocell using a cadmium sulphide crystal mounted in a shock-resistant structure that provides the device with protection from thermal shock.

2,839,646 Photocell Structure—F. A. Hester. Assignee: Clairex Corporation. A radiation sensitive photocell structure that provides protection against mechanical and thermal shock for the cadmium sulphide embedded therein.

2,839,675 Attenuator Of Noise In Radio Sets—H. Neumann. Assignee: International Standard Electric Corporation. A diode noise attenuating circuit coupled to the discriminator circuit of an F.M. receiving set.

2,839,686 Transistor Circuit—H. E. Tompkins. Assignee: Burroughs Corp. A transistorized multivibrator circuit having low power requirements.

2,839,690 Circuit For Energizing Light Amplifier Devices—B. Kazan. Assignee: R.C.A. Energizing means for an electroluminescent device wherein the individual

materials of the device are selectively energized to provide increased amplifier gain.

2,839,693 Electronic Computer Power Supply Circuits—R. C. Weise Assignee: Burroughs Corporation. A regulated power supply system for a digital computer, said system being one which is not dependent upon feedback regulation loops.

June 24, 1958

2,840,489 Process For The Controlled Deposition of Silicon Dihalide Vapors Onto Selected Surfaces—C. P. Kempter, C. Alvarez—Tostado. Assignee: Owens-Illinois Glass Company. Means for depositing a thin crystallized layer upon a selected surface by erothermically decomposing an unstable lower halide of the elements onto said surface.

2,840,494 Manufacture of Transistors—H. W. Parker. Assignee: None. A manufacturing method involving the epitaxial deposition of a film of *p*-type germanium onto a base layer of *n*-type germanium by bursts of a true metal gas.

2,840,495 Method of Processing Semiconductive Materials—R. G. Treuting. Assignee: Bell Telephone Laboratories. A method of producing *p-n* junctions in silicon and germanium by permanently deforming the *n*-type portion of a semiconductor body to introduce acceptor predominance, and thus convert said portion to *p*-type conductivity.

2,840,496 Semiconductor Device—D. A. Jenny. Assignee: R.C.A. A method for forming an electrode fused to a body of semiconducting cadmium telluride having a *p-n* junction associated with said body.

2,840,497 Junction Transistors and Process for Producing Them—R. L. Longini. Assignee: Westinghouse Electric Corporation. A double diffusion method for producing *p-n-i-p*, or *n-p-i-n* type junction transistors.

June 24, 1958

2,840,699 Transistor Squelch System Or The Like—F. C. Carpenter, Jr. Assignee: Hoffman Electronics Corporation. A squelch system that may be selectively adjusted for the level of squelch operation desired.

2,840,710 Electrical Crystal Unit—S. L. Levy. Assignee: Sylvania Electric Products Inc. A coaxial crystal cartridge with an interval high impedance *d-c* return path connecting the center conductor and the cartridge shell, said path providing reduction in input signal loss at low microwave frequencies.

2,840,726 Transistor Current Gate—D. J. Hamilton. Assignee: Hughes Aircraft Company. A gate circuit that eliminates a coupling capacitor between the gate and the flip-flop input thereby eliminating a time lag inherent with the use of said capacitor.

2,840,727 Self-Locking Transistor Switching Circuit—W. B. Guggi. Assignee: Westinghouse Electric Corporation. A transistorized bistable switching circuit.

2,840,728 Non-Saturating Transistor Circuits—G. Haugk, K. K. Kennedy. Assignee: Bell Telephone Laboratories. A transistor bistable multivibrator or flip-flop circuit in which neither transistor can be driven into saturation.

2,840,741 Electroluminescent Cell—W. Lehmann. Assignee: Westinghouse Electric Corporation. An electroluminescent cell in which the phosphor particles are embedded throughout a dielectric in a plurality of substantially straightline particle groupings which are oriented in a direction perpendicular to the electrodes.

2,840,770 Semiconductor Device and Method of Manufacture—E. D. Jackson. Assignee: Texas Instruments Incorporated. A semiconductor diode containing a silicon wafer of one conductivity type, a silver wire forming an ohmic contact with said wafer, and a wire connector that produces an opposite type conductivity in the silicon, thus forming a *p-n* junction therewith.

July 1, 1958

2,804,885 Semiconducting Amplifiers—I. G. Cresswell. Assignee: Marconi Wireless Telegraph Co. Ltd. A method of making a semiconductor amplifier including the steps of forming a grown junction, producing a visible step at the junction location by electrolytic etching, and providing an alloy junction to serve as an emitter.

2,841,477 Photochemically Activated Gaseous Etching Method—T. C. Hall Assignee: Pacific Semiconductors Inc. An etching method comprising the steps of immersing the body to be etched in an inactive vapor of a photolyzable gas and directing a beam of ultraviolet light upon said body at the portion to be etched.

2,841,503 Film Forming Hydrosols of Barium Titanate, Their Precipitation and A Substrate Coated Therewith—B. Grahm, G. D. Patterson. Assignee: E. I. DuPont de Nemours and Co. A composition containing barium titanate from which thin continuous films of titanate can be applied to substrates.

\*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.



2,841,508 Electrical Circuit Elements—R. R. Roup, J. S. Kelby. Assignee: Globe-Union Inc. An electrical circuit element having a body of high dielectric constant material having throughout properties of a semiconductor, and a conducting electrode secured to the surface of said device.

2,841,509 Method of Doping Semiconductive Material—R. V. Hensen, R. A. Laff. Assignee: R.C.A. A method of doping a semiconductive material in its molten phase with an impurity whose boiling point is lower than the melting point of said semiconductor.

2,841,510 Method of Producing P-N Junctions In Semiconductor Materials—S. E. Mayer. Assignee: International Standard Electric Corporation. A method of preventing the unwanted spreading of a deposited significant impurity element over the surface of a crystal.

2,841,650 Telephone Alert System—R. L. Koehler. Assignee: Koiled Kords Inc. A system for alerting a large number of stations over existing telephone circuits without interference with normal telephone operation.

2,841,700 Remote Control Apparatus—F. C. Hallden. Assignee: Hazeltine Research Inc. A remote control apparatus including a transistorized oscillator, an energy storage device coupled to said oscillator, and a transistor  $r$ - $f$  oscillator.

2,841,702 Semiconductor Automatic Gain Control System—L. E. Barton. Assignee: R.C.A. a transistorized AGC system for a radio receiver, said system providing an effect that may be delayed so that the output signal shows minimum distortion.

2,841,703 Transistor Mixer Circuit With Gain Control—C. C. Bopp, R. W. Bradmiller. Assignee: Avco Manufacturing Corp. In a transistorized receiver, a system of gain control which has a d-c power required to control the gain of the i-f amplifier circuit.

2,841,712 Transistor Sweep Generators—H. H. Hoge, D. L. Spotten. Assignee: Westinghouse Electric Corporation. A transistor sweep generator which is triggered by the Zener current flowing through a silicon junction diode.

2,841,719 Diode Gate and Its Control Circuit—A. J. Radcliffe Jr. Assignee: International Telephone and Telegraph corporation. A gate used in a telegraph transmission system for removing a carrier from a line and replacing it under signal control.

2,841,730 Single Crystal Electroluminescence—W. W. Piper. Assignee: General Electric Company. An electroluminescent cell comprising a single crystal of an activated phosphor material from the group consisting of zinc sulfide, zinc selenide, cadmium sulfide and cadmium selenide; and a pair of electrodes connected to and at opposite faces of said crystal.

2,841,746 Protective Circuit—D. D. Mawhinney. Assignee: R.C.A. A transistorized current overload protective system for electrical devices.

2,841,749 Selenium Rectifier—G. Eannarino, R. Parsons. Assignee: Sarks Tarzian Inc. A rectifier comprising an aluminum

base plate, a layer of selenium thereon, a barrier layer on said selenium, and a counter electrode on said barrier, said barrier being formed by coating the selenium with a dilute solution of an organic substance and an acid of selenium.

2,841,757 Electrical Regulator—C. B. Brake Co. A transistorized current regulating circuit suitable for use in low voltage applications.

# July 8, 1959

2,841,860 Semiconductor Devices and Methods—F. Koury. Assignee: Sylvania Electric Products, Inc. A method for growing a semiconductor crystal, cylindrical in shape, have coaxial regions of opposite conductivity, i.e. an inner cylinder of one conductivity type surrounded by an outer cylinder of the opposite conductivity type.

2,842,166 Forming Apparatus for Semiconductor Translating Device Components—F. Wohlman, Jr. Assignee: Hughes Aircraft Company. A method and apparatus which provides support and insures proper alignment and positioning of translating device components relative to forming dies, said method and apparatus thereby permitting the performance of multiple operations on said components.

2,842,466 Method of Making P-N Junction Semiconductor Unit—J. W. Moyer. Assignee: General Electric Company. A method for controlling the depth and location of the  $p$ - $n$  junction relative to the surface of the element, and for controlling the activating element concentration and gradient in the junction region.

2,842,467 Method of Growing Semiconductors—R. W. Landauer, L. P. Hunter. Assignee: International Business Machines. Method and apparatus for maintaining control over the distribution of impurities in semiconducting crystals, forming  $p$ - $n$  junctions therein, and controlling the specific resistance thereof.

2,842,468 Vapor Deposition of Single Crystals—S. S. Brenner. Assignee: General Electric Company. A method for producing high strength rod-like single crystals of metal by deposition from a metal vapor provided by decomposition of a volatile metal compound at normal atmospheric pressure, and forming said crystal on a substrate at a rate less than that at which imperfections are introduced.

2,842,623 Transistor Amplifier For Telephone Instrument—P. N. Lehr. Assignee: Dictograph Products Company, Incorporated. A transistor amplifier designed to fit into the hand receiver portion of a telephone set and provide supplemental amplification therefore, said amplifier being controlled by an on-off switch which is actuated at the will of the user.

2,842,624 Transistor Amplifier Circuit—R. E. Marsh. Assignee: The Hallicrafters Company. A two stage amplifier utilizing both point contact and junction transistor components.

2,842,682 Reversible Shift Register—G. L. Clapper. Assignee: International Business Machines. A shift register in which the state of each individual trigger is changed only when the condition is required to be changed.

2,842,683 Pulse Generating Circuit—R. J. Simon. Assignee: Carter Motor Company.

A square wave pulse generator capable of generating pulses which are, to a great extent, independent of input wave form and which can be made to last over a wide range of periods.

2,842,723 Controllable Asymmetric Electrical Conductor Systems—W. Koch, H. U. Harten, R. Thedieck. Assignee: Licentia Patent-Verwaltungs G.M.B.H. (Germany). An electrode arrangement for a semiconductor element that minimizes the effects of the size and position of the main electrode on the transformation zone.

2,842,724 Conductor Devices and Method of Making The Same—R. Thedieck. Assignee: Licentia Patent-Verwaltungs G.M.B.H. (Germany). A device in which point electrodes can be secured to the body of the semiconductor, thereby reducing the effects of mechanical vibration and heat expansion upon the operational characteristics of the device.

2,842,725 Directional Conductor Device and Method of Making It—W. Muller. Assignee: Siemens and Halske Aktiengesellschaft (Germany). A point-contact directional conductor surrounded by a mass of non-aqueous cellulose derivative which hardens to form an envelope, or a mass of insulating material such as paraffin, wax, resin, or polyesterol.

2,842,744 Balanced Modulator Circuit—R. L. Frank. Assignee: Sperry Rand Corporation. A balanced modulator providing double-balanced full-wave operation with a single-ended output in which there is no transformer loading in the output.

# July 15, 1958

2,842,830 Process For The Manufacture of Selenium Rectifier—O. J. Klein. Assignee: International Standard Electric Corporation. A method, which in the manufacture of selenium rectifiers, permits the combination in one plate of the characteristics of plates having either sprayed-on counter-electrodes or melted-on electrodes.

2,842,831 Manufacture of Semiconductor Devices—W. G. Pfann. Assignee: Bell Telephone Laboratories. A method for placing two or more electrodes in close proximity by a masking process which avoids conventional jig type arrangements.

2,842,841 Method of Soldering Leads To Semiconductor Devices—G. L. Schnable, J. Roschen. Assignee: Philco Corporation. A method of soldering leads to semiconductor devices in which a propylene glycol fluxing solution is maintained at a temperature high enough to melt the indium cadmium solder.

2,843,458 Process of Producing Silicon Tetrachloride—R. D. Beattie, L. P. Michel, C. A. Stokes. Assignee: Godfrey L. Cabot, Incorporated. A process for producing silicon tetrachloride from a charge composed of 50-80% silicon carbide, 3-10% carbon, and 17-45% unreduced siliceous matter, by raising the charge temperature to 900° C and treating said charge with chlorine gas.

2,843,511 Semiconductor Devices—J. L. Pankove. Assignee: Radio Corporation of America. A semiconductor body having a surface film separated from the bulk of the body by a rectifying barrier which provides an electric field that repels minority carriers from the surface, thereby minimizing the surface recombination velocity in said device.



# CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

## MANUFACTURERS

|       |  |       |  |
|-------|--|-------|--|
| EG—   | Allgemeine Elektricitäts-Gesellschaft                | MUL—  | Mullard, Ltd.  |
| EL—   | Associated Electrical Industries, Ltd.               | NAE—  | North American Electronics                           |
| MP—   | Amperex Electronic Corp.                             | NPC—  | Nucleonic Products Co., Inc.                         |
| UD—   | Audio Devices, Inc.                                  | OHM—  | Ohmite Manufacturing Co.                             |
| EN—   | Bendix Corp.   | PHI—  | Philco Corp. Lansdale Division                       |
| ER—   | Berkshire Labs                                       | PHIN— | Philips Gloeilampenfabrieken, Eindhoven, Netherlands |
| OG—   | Bogue Electric Mfg. Co.                              | PLEB— | The Plessey Co.                                      |
| OM—   | Bomac Labs   | PSI—  | Pacific Semiconductors, Inc.                         |
| RA—   | Bradley Semiconductor Corp.                          | QSC—  | International Diode Corp.                            |
| BS—   | CBS Electronics                                      | RADF— | La Radiotechnique, Div. Tubes Electroniques          |
| DC—   | Continental Device Corp.                             | RAY—  | Raytheon Company                                     |
| OL—   | Columbus Electronics Corp.                           | RCA—  | Radio Corporation of America, Semiconductor Div.     |
| TP—   | Clevite Transistor Products, Inc.                    | RHE—  | Rheem Semiconductor Corp.                            |
| SF—   | Compagnie Generale de T.S.F.                         | ROSG— | Dr. Ing. Rudolph Rost                                |
| AL—   | Dallons Semiconductor                                | SAR—  | Sarkes Tarzian, Inc., Rectifier Division             |
| DEL—  | Delco Radio  | SCN—  | Semicon, Inc.  |
| EVB—  | English Electric Valve Co., Ltd.                     | SEM—  | Semi-Elements Inc.                                   |
| RI—   | Eric Resistor Corp.                                  | SIE—  | Siemens & Halske Aktiengesellschaft                  |
| AN—   | Fansteel Metallurgical Corp.                         | SIL—  | Silicon Transistor Corp.                             |
| ERB—  | Ferranti Ltd.  | SOIF— | Societe Industriale de Liaisons, Paris 8e, France    |
| AH—   | Gahagan, Inc.  | SONY— | Sony Corp.   |
| ECB—  | General Electric Co., Ltd.                           | SSD—  | Sperry Semiconductor Division                        |
| IE—   | General Electric Company, Semiconductor Div.         | SSP—  | Solid State Products, Inc.                           |
| ELC—  | Canadian General Electric Co.                        | STC—  | Shockley Transistor Corp.                            |
| IC—   | General Instrument Corp.                             | STCB— | Standard Telephone & Cables, Ltd.                    |
| ITC—  | General Transistor Corp.                             | SYL—  | Sylvania Electric Products, Inc.                     |
| IAFO— | Institutet for Halvedarforskning                     | SYN—  | Syntron Co.  |
| ISD—  | Hoffman Semiconductor Division                       | TEX—  | Texas Research Assoc.                                |
| ITJ—  | Hitachi Ltd., Mushashi Works                         | TFKG— | Telefunken, Ltd.                                     |
| IUG—  | Hughes Products Division                             | TI—   | Texas Instruments Incorporated                       |
| NRB—  | International Rectifier Co., Ltd.                    | TKD—  | Tekade, Nurnberg, Germany                            |
| NRC—  | International Rectifier Corp.                        | TOK—  | Tokyo Tsushin Kogyo, Ltd.                            |
| RC—   | International Resistance Co.                         | TRA—  | Transitron Electronic Corp.                          |
| TT—   | International Tel. & Tel. Corp.                      | TUN—  | Tung-Sol Electric, Inc.                              |
| CEM—  | Kemtron Electron Products, Inc.                      | TSC—  | Trans-Sil Corp.                                      |
| CTF—  | Laboratoire Central de Telecommunications            | UCI—  | United Components                                    |
| ATJ—  | P. R. Mallory & Co., Inc.                            | USD—  | United States Dynamics Corp.                         |
| JAL—  | Matushita Electronics Corp., Takatsuki, Osaka, Japan | USS—  | U. S. Semiconductor Products, Inc.                   |
| MC—   | Microwave Associates, Inc.                           | VIC—  | Vickers Inc.   |
| MFI—  | Microfarad   | WEC—  | Western Electric Co.                                 |
| MOT—  | Motorola, Inc.                                       | WEST— | Westinghouse Electric Corp.                          |

## CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

| TYPE NO. | CLASSIFICATION | DESCRIPTION  | MFR. |
|----------|----------------|--|------|
| 1N2771   | 1              | Power Monitoring Diode for UHF   | MIC  |
| 1N3093   | 2              | X-band Switch for Waveguide Mounting   | PHI  |
| 1N3096R  | 2              | Gallium Arsenide K-band Mixer Diode  | PHI  |
| MA441    | 2              | Ridged Waveguide mounted broad band Video Detector; mica window seal; min. sensitivity-27dbm over 40 to 75 KMC freq. range for 2.5 MC bandwidth and 100 KC min. low freq. cutoff of Video Amplifier. | MIC  |
| MA449A   | 2              | Fixed base cartridge equivalent to 1N21 series of  | MIC  |
| MA449B   | 2              | same alphabetical suffix letter with guaranteed  | MIC  |
| MA449C   | 2              | performance at 150 deg. C and hermetic solder  | MIC  |
| MA449D   | 2              | sealing.   | MIC  |
| MA449E   | 2              |  | MIC  |
| MA452    | 2              | Video Detector interchangeable with MA408 Video  | MIC  |
| MA452A   | 2              | Detector with additional guarantee of 150 deg. C   | MIC  |
| MA452B   | 2              | rating and hermetic sealing.   | MIC  |
| MA453A   | 2              | Fixed base cartridge equivalent to 1N23 series of  | MIC  |
| MA453B   | 2              | same alphabetical suffix letter with guaranteed  | MIC  |
| MA453C   | 2              | performance at 150 deg. C and hermetic solder  | MIC  |
| MA454C   | 2              | sealing.   | MIC  |
| MA454D   | 2              |  | MIC  |
| MA454E   | 2              |  | MIC  |
| PHG1     | 4              | Sens.100ma/Lumen;dark I-10ua/30V/25 deg. C   | NPC  |
| PHG2     | 4              | Sens. 30ma/Lumen;dark I-10ua/30V/25 deg. C   | NPC  |
| S11      | 1,2            | S1; S Band; Test freq.-3060Mc;Conv.Loss 6.5db max  | ROSG |
| S15      | 2              | UHF Detector; 5.0ma at 1.0 V   | ROSG |
| S110     | 2              | UHF Detector; 10ma at 1.0 V  | ROSG |
| STC135   | S1 Stabistor   | .64V ± 10 per cent at 1ma If at 25 deg. C; IR-.1ua max at 2 V.   | SIL  |
| STC235   | S1 Stabistor   | .70 -.74V at 10ma If at 25 deg. C; IR-.1ua max at 6 V.   | SIL  |
| WX809A   | 8,9            | S1; VBO - 50V; PRV- 60V; If -50A max   | WEST |
| WX809B   | 8,9            | S1; VBO -100V; PRV-120V; If -50A max   | WEST |
| WX809C   | 8,9            | S1; VBO -150V; PRV-180V; If -50A max   | WEST |
| WX809D   | 8,9            | S1; VBO -200V; PRV-240V; If -50A max   | WEST |
| WX809E   | 8,9            | S1; VBO -250V; PRV-300V; If -50A max   | WEST |
| WX809F   | 8,9            | S1; VBO -300V; PRV-360V; If -50A max   | WEST |
| WX822A   | 10             | Ip/Iv -8.0; Ip 2.0ma ± 5 per cent Iv -.32ma max  | WEST |
| WX822B   | 10             | Ip/Iv -8.0; Ip 5.0ma ± 3 per cent Iv -.80ma max  | WEST |

### Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
3. Varactor diodes
4. Photodiodes
5. Solar Cells
6. Harmonic generator diodes
7. 4-Layer bistable diodes
8. Controlled rectifier
9. PNP switch
10. Tunnel diode
11. Photoconductive cell



# DIODES and RECTIFIERS

| TYPE NO. | USE<br>See Code Below | MAT | PIV<br><br>(volts) | MAX. CONT. WORK. VOLT.<br><br>(volts) | Min. Forward Current @ 25°C     |         | MAX. D.C. OUTPUT CURRENT <sup>1</sup> @ T (°C)<br><br>(amps) | MAX. FULL LOAD VOLT. DROP <sup>4</sup><br><br>(volts) | Max. Rev. Current                   |         |      | MFR.<br>{ See code at start of charts } |      |
|----------|-----------------------|-----|--------------------|---------------------------------------|---------------------------------|---------|--|---|-------------------------------------|---------|------|---|------|
|          |                       |     |                    |                                       | I <sub>f</sub> @ E <sub>f</sub> |         |  |   | I <sub>b</sub> @ E <sub>b</sub> @ T |         |      |   |      |
|          |                       |     |                    |                                       | (mA)                            | (volts) |  |   | (uA)                                | (volts) | (°C) |   |      |
| D4010    | 2                     | Si  | 400                | 400                                   | 10A                             | 1.5     | 10   | 125C  | 20                                  | 400     | 25C  | PLEB                                    |      |
| GW106    | 1                     | Ge  |                    | 100                                   | 10                              | .25     |  |   | 5.0                                 | 1.5     | 60   | ROSG                                    |      |
| GW107    | 1                     | Ge  |                    | 20                                    | 100                             | .75     |  |   |                                     |         |      | ROSG                                    |      |
| GW108    | 1                     | Ge  |                    | 60                                    | 5.0                             | 1.0     |  |   | 75                                  | 60      | 60   | ROSG                                    |      |
| MP100    | 2                     | Si  | 100                |                                       | 400                             | 1.0     | .05  | 200   | 75                                  |         | 200  | GIC                                     |      |
| MP225    | 2                     | Si  | 225                |                                       | 400                             | 1.0     | .05  | 200   | 75                                  |         | 200  | GIC                                     |      |
| MP300    | 2                     | Si  | 300                |                                       | 400                             | 1.0     | .04  | 200   | 75                                  |         | 200  | GIC                                     |      |
| MP400    | 2                     | Si  | 400                |                                       | 400                             | 1.0     | .035   | 200   | 75                                  |         | 200  | GIC                                     |      |
| MP500    | 2                     | Si  | 500                |                                       | 400                             | 1.0     | .025   | 200   | 75                                  |         | 200  | GIC                                     |      |
| MP600    | 2                     | Si  | 600                |                                       | 400                             | 1.0     | .02  | 200   | 75                                  |         | 200  | GIC                                     |      |
| MS1H     | 1                     | Si  | 60                 | 60                                    | 200                             | 1.0     | .25  | 25  | 50                                  | 60      | 150  | AEI                                     |      |
| MS2H     | 1                     | Si  | 100                | 100                                   | 200                             | 1.0     | .25  | 25  | 50                                  | 100     | 150  | AEI                                     |      |
| MS3H     | 1                     | Si  | 150                | 150                                   | 200                             | 1.0     | .25  | 25  | 100                                 | 150     | 150  | AEI                                     |      |
| MS4H     | 1                     | Si  | 200                | 200                                   | 200                             | 1.0     | .25  | 25  | 100                                 | 200     | 150  | AEI                                     |      |
| MS5H     | 1                     | Si  | 300                | 300                                   | 200                             | 1.0     | .25  | 25  | 100                                 | 300     | 150  | AEI                                     |      |
| OS32     | 1                     | Si  | 15                 | 12                                    | 10                              | 1.0     | .10  | 25  | 1.4                                 | .10     | 12   | TKD                                     |      |
| OS33     | 1                     | Si  | 60                 | 50                                    | 10                              | 1.0     | .10  | 25  | 1.4                                 | .10     | 50   | TKD                                     |      |
| OS34     | 1                     | Si  | 110                | 100                                   | 10                              | 1.0     | .10  | 25  | 1.4                                 | .10     | 100  | TKD                                     |      |
| OS35     | 1                     | Si  | 160                | 150                                   | 10                              | 1.0     | .10  | 25  | 1.4                                 | .10     | 150  | TKD                                     |      |
| OS36     | 1                     | Si  | 350                | 320                                   | 10                              | 1.0     | .10  | 25  | 1.4                                 | 10      | 320  | TKD                                     |      |
| 1M4      | 3                     | Si  | 100                | 100                                   | 400                             | 1.0     | .40  | 25A   | .20                                 | 100     | 25A  | PLEB                                    |      |
| 1N2327   |                       | Si  |                    | 1000                                  | 400                             | 3.3     |  |   | 1.5                                 | 750     | 25   | WEC                                     |      |
| 1N2328   |                       | Si  |                    | 2000                                  | 400                             | 3.3     |  |   | 1.5                                 | 1500    | 25   | WEC                                     |      |
| 1N2791   |                       | Si  |                    | 350                                   | 50                              | 1.3     |  |   | .05                                 | 300     | 25   | WEC                                     |      |
| 1NA1     | 1                     | Ge  |                    | 75                                    | 5.0                             | 1.0     |  |   | 500                                 | 50      | 25   | KOKJ                                    |      |
| 1NA2     | 1                     | Ge  |                    | 125                                   | 4.0                             | 1.0     |  |   | 600                                 | 10      | 25   | KOKJ                                    |      |
| 1NA3     | 1                     | Ge  |                    | 170                                   | 3.0                             | 1.0     |  |   | 500                                 | 150     | 25   | KOKJ                                    |      |
| 1NA4     | 1                     | Ge  |                    | 60                                    | 3.0                             | 1.0     |  |   | 800                                 | 50      | 25   | KOKJ                                    |      |
| 1NA5     | 1                     | Ge  |                    | 75                                    | 5.0                             | 1.0     |  |   | 100                                 | 50      | 25   | KOKJ                                    |      |
| 1NA6     | 1                     | Ge  |                    | 50                                    | 15                              | 1.0     |  |   | 300                                 | 30      | 25   | KOKJ                                    |      |
| 1NA7     | 1                     | Ge  |                    | 120                                   | 4.0                             | 1.0     |  |   | 500                                 | 100     | 25   | KOKJ                                    |      |
| 1NA9     | 1                     | Ge  |                    | 35                                    | 3.0                             | 1.0     |  |   | 80                                  | 10      | 25   | KOKJ                                    |      |
| 5T3N     | 2                     | Si  | 50                 | 35                                    |                                 |         | 50   | 100A  | .50                                 | 60ma    | 50   | SAR                                     |      |
| 5T3P     | 2                     | Si  | 50                 | 35                                    |                                 |         | 50   | 100A  | .50                                 | 60ma    | 50   | SAR                                     |      |
| 10AS     | 1                     | Si  | 100                | 100                                   | 500                             | 1.15    | .50  | 50A   |                                     | 50      | 100  | 50A                                     | PLEB |
| 10T3N    | 2                     | Si  | 100                | 70                                    |                                 |         | 50   | 100A  | .50                                 | 60ma    | 100  | 25                                      | SAR  |
| 10T3P    | 2                     | Si  | 100                | 70                                    |                                 |         | 50   | 100A  | .50                                 | 60ma    | 100  | 25                                      | SAR  |
| 12G4     | 2                     | Si  | 1200               | 1200                                  | 400                             | 1.5     | .40  | 25A   |                                     | 20      | 1200 | 25A                                     | PLEB |
| 20AS     | 1                     | Si  | 200                | 200                                   | 500                             | 1.15    | .50  | 50A   |                                     | 50      | 200  | 50A                                     | PLEB |
| 20T3N    | 2                     | Si  | 200                | 140                                   |                                 |         | 50   | 100A  | .50                                 | 60ma    | 200  | 25                                      | SAR  |
| 20T3P    | 2                     | Si  | 200                | 140                                   |                                 |         | 50   | 100A  | .50                                 | 60ma    | 200  | 25                                      | SAR  |
| 30T3N    | 2                     | Si  | 300                | 210                                   |                                 |         | 50   | 100A  | .50                                 | 30ma    | 300  | 25                                      | SAR  |
| 30T3P    | 2                     | Si  | 300                | 210                                   |                                 |         | 50   | 100A  | .50                                 | 30ma    | 300  | 25                                      | SAR  |
| 40AS     | 1                     | Si  | 400                | 400                                   | 500                             | 1.15    | .50  | 50A   |                                     | 50      | 400  | 50A                                     | PLEB |
| 40T3N    | 2                     | Si  | 400                | 280                                   |                                 |         | 50   | 100A  | .50                                 | 30ma    | 400  | 25                                      | SAR  |
| 40T3P    | 2                     | Si  | 400                | 280                                   |                                 |         | 50   | 100A  | .50                                 | 30ma    | 400  | 25                                      | SAR  |
| 60AS     | 1                     | Si  | 600                | 600                                   | 500                             | 1.15    | .50  | 50A   |                                     | 50      | 600  | 50A                                     | PLEB |
| 80AS     | 1                     | Si  | 800                | 800                                   | 500                             | 1.15    | .50  | 50A   |                                     | 50      | 800  | 50A                                     | PLEB |
| D1010    | 2                     | Si  | 100                | 100                                   | 10A                             | 1.5     | 10   | 125C  |                                     | 20      | 100  | 25C                                     | PLEB |
| D2010    | 2                     | Si  | 200                | 200                                   | 10A                             | 1.5     | 10   | 125C  |                                     | 20      | 200  | 25C                                     | PLEB |

## NOTATIONS

### Under Use

- General Purpose
- Power Rectifier
- Magnetic Amplifier
- Insulated Base
- Controlled Rectifier
- Dual Rectifier
- Direct Tube Replacement
- Controlled Forward Conductance

### Other

- For half wave resistive load average over 1 cycle

### Under Reverse Current

☒ Dynamic

### Under Mfr.

- Available in stock form from that manufacturer

Following any temperature reading these symbols apply

- A — Ambient  
C — Case  
J — Junction  
S — Storage  
△ — Inlet Temperature of Coolant

### Type No.

† — Revised Data

Manufacturers should be contacted for value and test conditions for surge current and maximum peak recurrent current

### Under E<sub>f</sub>

□ — at 125°C

## SWITCHING DIODES

| TYPE NO. | MAT | PIV<br><br>(volts) | MAX. CONT. REV. WORK. VOLT.<br><br>(volts) | Min. Forward Current<br>@ 25°C |         | MAX. REVERSE CURRENT<br>@ 25°C |         | Recovery Characteristics                           |                               |        | MFR.<br>{ See code at start of charts } |
|----------|-----|--------------------|--|--------------------------------|---------|--------------------------------|---------|--|-------------------------------|--------|---|
|          |     |                    |  | $I_f @ E_f$                    |         | $I_b @ E_b$                    |         | TEST CONDITIONS                                    | $Z_{rec.} @ \text{time } (t)$ |        |   |
|          |     |                    |  | (mA)                           | (volts) | ( $\mu A$ )                    | (volts) | Fwd. Rev.<br>$I_f \text{ to } E_b$<br>(mA) (volts) | (K ohms)                      | (usec) |   |

|      |    |     |     |     |     |     |     |     |    |     |     |      |
|------|----|-----|-----|-----|-----|-----|-----|-----|----|-----|-----|------|
| 1S83 | Ge | 80  | 80  | 250 | .50 | 60  | 80  | 100 | 10 | 500 | 8.0 | HITJ |
| 1S84 | Si | 200 | 200 | 100 | 1.0 | 2.0 | 200 | 100 | 10 | 500 | 8.0 | HITJ |
| 1S85 | Si | 100 | 100 | 100 | 1.0 | 2.0 | 200 | 100 | 10 | 500 | 8.0 | HITJ |



# VOLTAGE VARIABLE CAPACITOR DIODES

| TYPE NO.         | CAPACITANCE<br>C @ E <sub>b</sub> |         | PIV | Q @ FREQ.         |         | MFR. |
|------------------|-----------------------------------|---------|-----|-------------------|---------|------|
|                  | (uuf)                             | (volts) |     | Min. Q            | (mc)    |      |
| 1S85             | 14-26                             | 10      | 20  | 3.0               | 240     | HITJ |
| BA410            | 10                                | 4.0     | 60  | 50                | 50      | TKD  |
| GA53694-1        | 3.55-3.85                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53694-2        | 3.80-4.20                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53694-3        | 4.15-4.45                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53694-4        | 3.55-4.45                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53695-1        | 3.55-3.85                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53695-2        | 3.80-4.20                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53695-3        | 4.15-4.45                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| GA53695-4        | 3.55-4.45                         | 0.0     | 5.5 | 3.1 $\frac{1}{2}$ | 9000    | WEC  |
| MA4253 $\square$ | 1.4max                            | 0.0     | 6.0 | 120 KMC           | cutoff  | MIC  |
| MA4280 $\Delta$  | .20- .40                          | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4281 $\Delta$  | .40- .80                          | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4282 $\Delta$  | .80-1.6                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4283 $\Delta$  | 1.2-2.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4284 $\Delta$  | 2.0-3.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4285 $\Delta$  | 3.0-5.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4286 $\Delta$  | 5.0-7.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4287 $\Delta$  | 7.0- 10                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4288 $\Delta$  | 10- 15                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4289 $\Delta$  | 15- 20                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4290 $\Delta$  | 20- 25                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4291 $\Delta$  | 25- 30                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4292 $\Delta$  | 30- 35                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4297 $\Delta$  | 2.0max                            | 6.0     | 6.0 | 120 KMC           | cutoff  | MIC  |
| MA4380 $\dagger$ | .20-.40                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4381 $\dagger$ | .40-.80                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4382 $\dagger$ | .80-1.6                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4383 $\dagger$ | 1.2-2.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4384 $\dagger$ | 2.0-3.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4385 $\dagger$ | 3.0-5.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4386 $\dagger$ | 5.0-7.0                           | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4387 $\dagger$ | 7.0-10                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |
| MA4388 $\dagger$ | 10- 15                            | 6.0     | 30  | 20-30 KMC         | typical | MIC  |

Under Type No.  
 $\dagger$  - Sub Miniature Glass  
 $\Delta$  - Miniature Pill Varactor  
 $\square$  - Double-ended Varactor

The following manufacturers have announced that they have begun supplying the indicated previously registered devices.

CBS ELECTRONICS:  
 1N482, 1N483, 1N484, 1N485, 1N625, 1N626, 1N627, 1N628, 1N629

CLEVITE TRANSISTOR:  
 1N646 thru 1N649, 1N676 thru 1N679, 1N681 thru 1N687, 1N689

COLUMBUS ELECTRONICS:  
 1N283 thru 1N286, 1N338, 1N340, 1N347, 1N1341 thru 1N1348, 1N1730 thru 1N1734, 1N2160, 1N2382, 1N2383

CORNELL-DUBILIER ELECTRIC:  
 1N1199 thru 1N1206, 1N1341 thru 1N1348, 1N2194 thru 1N2201, 1N2204 thru 1N2211

GENERAL INSTRUMENT:  
 1N1730, 1N1731, 1N2373, 1N2374, 1N2375, 1N2376, 1N2377, 1N2378, 1N2379, 1N2380, 1N2381, 1N2382, 1N2383, 1N2384, 1N2385

HOFFMAN SEMICONDUCTOR:  
 1N482 thru 1N488, 1N659, 1N660, 1N661, 1N746 thru 1N759, 1N748A thru 1N759A, 1N821, 1N822, 1N1603 thru 1N1609, 1N1603A thru 1N1609A, 1N1816 thru 1N1836, 1N1818A thru 1N1838A, 1N1818R thru 1N1838R, 1N1818RA thru 1N1838RA, 1N2008 thru 1N2012, 1N2008R thru 1N2012R, 1N2008RA thru 1N2012RA, 1N2043 thru 1N2048, 1N2498 thru 1N2500, 1N2498A thru 1N2500A, 1N2498R thru 1N2500R, 1N2498RA thru 1N2500RA

NUCLEONIC:  
 1N1, 1N69A, 1N70A, 1N66A, 1N118A, 1N126A, 1N139, 1N140, 1N146, 1N198, 1N273, 1N276, 1N277, 1N279, 1N281, 1N282, 1N294, 1N298, 1N297, 1N309, 1N482, 1N478, 1N477, 1N641, 1N642, 1N616, 1N617, 1N636, 1N805

PHILCO:  
 1N26AMR, 1N26AR, 1N26BMR, 1N26BR, 1N26CMR, 1N26CR, 1N26MR, 1N26R, 1N78AMR, 1N78AR, 1N78BMR, 1N78BR, 1N78CMR, 1N78CR, 1N78DMR, 1N78DR, 1N78MR, 1N78R

SEMI-ELEMENTS:  
 1N36, 1N36, 1N39B, 1N40, 1N52A, 1N60A, 1N63A, 1N65, 1N66A, 1N71, 1N87, 1N87A, 1N89, 1N96, 1N96A, 1N97A, 1N98, 1N98A, 1N99A, 1N100, 1N100A, 1N108, 1N117A, 1N118, 1N118A, 1N127A, 1N128A, 1N137A, 1N139, 1N140, 1N141, 1N143, 1N144, 1N146, 1N209 thru 1N214, 1N270, 1N273, 1N276, 1N279, 1N281, 1N287, 1N288 thru 1N292, 1N294A, 1N297A, 1N298, 1N298A, 1N302, 1N304, 1N306, 1N307, 1N308, 1N310, 1N312, 1N313, 1N434, 1N447 thru 1N460, 1N462 thru 1N468, 1N468, 1N497 thru 1N500, 1N542, 1N634, 1N773, 1N773A, 1N774, 1N774A, 1N775, 1N776, 1N805

SILICON TRANSISTOR:  
 1N648, 1N646, 1N647, 1N708, 1N709, 1N710, 1N711, 1N712, 1N713, 1N714, 1N715, 1N716, 1N717, 1N718, 1N719, 1N720

TEKADI:  
 1N34, 1N48, 1N52, 1N54, 1N57, 1N60, 1N63, 1N64, 1N65, 1N67, 1N70, 1N81, 1N87, 1N295, 1N636

TUNG-SOL ELECTRIC:  
 1N253 thru 1N256, 1N338, 1N340, 1N347, 1N1183 thru 1N1198, 1N1291, 1N1292, 1N1294, 1N1296, 1N1396, 1N1397, 1N1398, 1N1399, 1N1400, 1N1401, 1N1402



# PART 2 NEW DIODES and RECTIFIERS

| TYPE NO. | USE<br>{ See Code Below } | MAT | PIV<br><br>(volts) | MAX. CONT. WORK. VOLT.<br><br>(volts) | Min. Forward Current<br>@ 25°C          |         | MAX. D.C. OUTPUT CURRENT <sup>4</sup> @ T (°C) |   | MAX. FULL LOAD VOLT. DROP <sup>4</sup><br><br>(volts) | Max. Rev. Current |      |       | MFR.<br>{ See code at start of charts } |
|----------|---------------------------|-----|--------------------|---------------------------------------|---|---------|--|---|---|-------------------|------|-------|---|
|          |                           |     |                    |                                       | I <sub>f</sub> @ E <sub>f</sub><br>(mA) | (volts) | (amps)   | I <sub>b</sub> @ E <sub>b</sub> @ T<br>(uA) |   | (volts)           | (°C) |       |   |
| 1N35     | 1                         | Ge  | 75                 | 60                                    | 20                                      | 1.0     |  |   |   | 500               | 50   |       | OHM                                     |
| 1N135    | 1                         | Ge  | 75                 | 60                                    | 5.0                                     | 1.0     |  |   |   | 800               | 50   |       | OHM                                     |
| 1N175    | 1                         | Ge  | 125                | 100                                   | 5.0                                     | 1.0     |  |   |   | 50                | 50   |       | OHM                                     |
| 1N947    | 1                         | S1  | 800                |                                       | 400                                     | 1.0     |  |   |   | 275-4             |      | 25    | WEC                                     |
| 1T26     | 1                         | Ge  | 40                 | 35                                    | 8.0                                     | 1.0     | .05  | 25A   |   | 80                | 10   | 25A   | SONY                                    |
| 4B11N    | 2                         | S1  | 50                 | 35                                    | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 35   | 140C  | FAN-6                                   |
| 4B11P    | 2                         | S1  | 50                 | 35                                    | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 35   | 140C  | FAN-6                                   |
| 4B12N    | 2                         | S1  | 100                | 71                                    | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 71   | 140C  | FAN-6                                   |
| 4B12P    | 2                         | S1  | 100                | 71                                    | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 71   | 140C  | FAN-6                                   |
| 4B13N    | 2                         | S1  | 150                | 106                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 106  | 140C  | FAN-6                                   |
| 4B13P    | 2                         | S1  | 150                | 106                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 106  | 140C  | FAN-6                                   |
| 4B14N    | 2                         | S1  | 200                | 142                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 142  | 140C  | FAN-6                                   |
| 4B14P    | 2                         | S1  | 200                | 142                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 142  | 140C  | FAN-6                                   |
| 4B15N    | 2                         | S1  | 250                | 177                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 177  | 140C  | FAN-6                                   |
| 4B15P    | 2                         | S1  | 250                | 177                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 177  | 140C  | FAN-6                                   |
| 4B16N    | 2                         | S1  | 300                | 212                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 212  | 140C  | FAN-6                                   |
| 4B16P    | 2                         | S1  | 300                | 212                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 212  | 140C  | FAN-6                                   |
| 4B17N    | 2                         | S1  | 350                | 247                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 247  | 140C  | FAN-6                                   |
| 4B17P    | 2                         | S1  | 350                | 247                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 247  | 140C  | FAN-6                                   |
| 4B18N    | 2                         | S1  | 400                | 284                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 284  | 140C  | FAN-6                                   |
| 4B18P    | 2                         | S1  | 400                | 284                                   | 35A                                     | 1.2     | 35   | 140C  | 1.7   | 10ma              | 284  | 140C  | FAN-6                                   |
| 6B11N    | 2                         | S1  | 50                 | 35                                    | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 35   | 150-5 | FAN-6                                   |
| 6B11P    | 2                         | S1  | 50                 | 35                                    | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 35   | 150-5 | FAN-6                                   |
| 6B12N    | 2                         | S1  | 100                | 71                                    | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 71   | 150-5 | FAN-6                                   |
| 6B12P    | 2                         | S1  | 100                | 71                                    | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 71   | 150-5 | FAN-6                                   |
| 6B13N    | 2                         | S1  | 150                | 106                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 106  | 150-5 | FAN-6                                   |
| 6B13P    | 2                         | S1  | 150                | 106                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 106  | 150-5 | FAN-6                                   |
| 6B14N    | 2                         | S1  | 200                | 142                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 142  | 150-5 | FAN-6                                   |
| 6B14P    | 2                         | S1  | 200                | 142                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 142  | 150-5 | FAN-6                                   |
| 6B15N    | 2                         | S1  | 250                | 177                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 177  | 150-5 | FAN-6                                   |
| 6B15P    | 2                         | S1  | 250                | 177                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 177  | 150-5 | FAN-6                                   |
| 6B16N    | 2                         | S1  | 300                | 212                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 212  | 150-5 | FAN-6                                   |
| 6B16P    | 2                         | S1  | 300                | 212                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 212  | 150-5 | FAN-6                                   |
| 6B17N    | 2                         | S1  | 350                | 247                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 247  | 150-5 | FAN-6                                   |
| 6B17P    | 2                         | S1  | 350                | 247                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 247  | 150-5 | FAN-6                                   |
| 6B18N    | 2                         | S1  | 400                | 284                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 284  | 150-5 | FAN-6                                   |
| 6B18P    | 2                         | S1  | 400                | 284                                   | 20A                                     | 1.2     | 20   | 150C  | 1.5   | 5000              | 284  | 150-5 | FAN-6                                   |
| 7B11N    | 1                         | S1  | 50                 | 35                                    | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 35   | 150-5 | FAN-6                                   |
| 7B11P    | 1                         | S1  | 50                 | 35                                    | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 35   | 150-5 | FAN-6                                   |
| 7B12N    | 1                         | S1  | 100                | 71                                    | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 71   | 150-5 | FAN-6                                   |
| 7B12P    | 1                         | S1  | 100                | 71                                    | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 71   | 150-5 | FAN-6                                   |
| 7B13N    | 1                         | S1  | 150                | 106                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 106  | 150-5 | FAN-6                                   |
| 7B13P    | 1                         | S1  | 150                | 106                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 106  | 150-5 | FAN-6                                   |
| 7B14N    | 1                         | S1  | 200                | 142                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 142  | 150-5 | FAN-6                                   |
| 7B14P    | 1                         | S1  | 200                | 142                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 142  | 150-5 | FAN-6                                   |
| 7B15N    | 1                         | S1  | 250                | 177                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 177  | 150-5 | FAN-6                                   |
| 7B15P    | 1                         | S1  | 250                | 177                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 177  | 150-5 | FAN-6                                   |
| 7B16N    | 1                         | S1  | 300                | 212                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 212  | 150-5 | FAN-6                                   |
| 7B16P    | 1                         | S1  | 300                | 212                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 212  | 150-5 | FAN-6                                   |
| 7B17N    | 1                         | S1  | 350                | 247                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 247  | 150-5 | FAN-6                                   |
| 7B17P    | 1                         | S1  | 350                | 247                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 247  | 150-5 | FAN-6                                   |
| 7B18N    | 1                         | S1  | 400                | 284                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 284  | 150-5 | FAN-6                                   |
| 7B18P    | 1                         | S1  | 400                | 284                                   | 12A                                     | 1.2     | 12   | 150C  | 1.5   | 10ma              | 284  | 150-5 | FAN-6                                   |
| 8B11N    | 2                         | S1  | 50                 | 35                                    | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 35   | 150-5 | FAN-6                                   |
| 8B11P    | 2                         | S1  | 50                 | 35                                    | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 35   | 150-5 | FAN-6                                   |
| 8B12N    | 2                         | S1  | 100                | 71                                    | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 71   | 150-5 | FAN-6                                   |
| 8B12P    | 2                         | S1  | 100                | 71                                    | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 71   | 150-5 | FAN-6                                   |
| 8B13N    | 2                         | S1  | 150                | 106                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 106  | 150-5 | FAN-6                                   |
| 8B13P    | 2                         | S1  | 150                | 106                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 106  | 150-5 | FAN-6                                   |
| 8B14N    | 2                         | S1  | 200                | 142                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 142  | 150-5 | FAN-6                                   |
| 8B14P    | 2                         | S1  | 200                | 142                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 142  | 150-5 | FAN-6                                   |
| 8B15N    | 2                         | S1  | 250                | 177                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 177  | 150-5 | FAN-6                                   |
| 8B15P    | 2                         | S1  | 250                | 177                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 177  | 150-5 | FAN-6                                   |
| 8B16N    | 2                         | S1  | 300                | 212                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 212  | 150-5 | FAN-6                                   |
| 8B16P    | 2                         | S1  | 300                | 212                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 212  | 150-5 | FAN-6                                   |
| 8B17N    | 2                         | S1  | 350                | 247                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 247  | 150-5 | FAN-6                                   |
| 8B17P    | 2                         | S1  | 350                | 247                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 247  | 150-5 | FAN-6                                   |
| 8B18N    | 2                         | S1  | 400                | 284                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 284  | 150-5 | FAN-6                                   |
| 8B18P    | 2                         | S1  | 400                | 284                                   | 70A                                     | 1.2     | 70   | 150C  | 1.2   | 15ma              | 284  | 150-5 | FAN-6                                   |
| 9A11N    | 1                         | S1  | 50                 | 35                                    | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 35   | 150-5 | FAN-6                                   |
| 9A11P    | 1                         | S1  | 50                 | 35                                    | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 35   | 150-5 | FAN-6                                   |
| 9A12N    | 1                         | S1  | 100                | 71                                    | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 71   | 150-5 | FAN-6                                   |
| 9A12P    | 1                         | S1  | 100                | 71                                    | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 71   | 150-5 | FAN-6                                   |
| 9A13N    | 1                         | S1  | 150                | 106                                   | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 106  | 150-5 | FAN-6                                   |
| 9A13P    | 1                         | S1  | 150                | 106                                   | 5000                                    | 1.2     | 5.0  | 150C  | 1.5   | 1000              | 106  | 150-5 | FAN-6                                   |



| TYPE NO. | USE<br>{ See Code Below } | MAT | PIV<br><br>(volts) | MAX. CONT. WORK. VOLT.<br><br>(volts) | Min. Forward Current @ 25°C     |         | MAX. D.C. OUTPUT CURRENT†<br><br>(amps) | T<br>@ (°C) | MAX. FULL LOAD VOLT. DROP‡<br><br>(volts) | Max. Rev. Current                   |         |       | MFR.<br>{ See code at start of charts } |
|----------|---------------------------|-----|--------------------|---------------------------------------|---------------------------------|---------|---|-------------|---|-------------------------------------|---------|-------|---|
|          |                           |     |                    |                                       | I <sub>f</sub> @ E <sub>f</sub> |         |   |             |   | I <sub>b</sub> @ E <sub>b</sub> @ T |         |       |   |
|          |                           |     |                    |                                       | (mA)                            | (volts) |   |             |   | (uA)                                | (volts) | (°C)  |   |
| 9A14N    | 1                         | S1  | 200                | 142                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 142     | 150-5 | FAN-6                                   |
| 9A14P    | 1                         | S1  | 200                | 142                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 142     | 150-5 | FAN-6                                   |
| 9A15N    | 1                         | S1  | 250                | 177                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 177     | 150-5 | FAN-6                                   |
| 9A15P    | 1                         | S1  | 250                | 177                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 177     | 150-5 | FAN-6                                   |
| 9A16N    | 1                         | S1  | 300                | 212                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 212     | 150-5 | FAN-6                                   |
| 9A16P    | 1                         | S1  | 300                | 212                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 212     | 150-5 | FAN-6                                   |
| 9A17N    | 1                         | S1  | 350                | 247                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 247     | 150-5 | FAN-6                                   |
| 9A17P    | 1                         | S1  | 350                | 247                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 247     | 150-5 | FAN-6                                   |
| 9A18N    | 1                         | S1  | 400                | 284                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 284     | 150-5 | FAN-6                                   |
| 9A18P    | 1                         | S1  | 400                | 284                                   | 5000                            | 1.2     | 5.0                                     | 150C        | 1.5                                       | 1000                                | 284     | 150-5 | FAN-6                                   |
| BC101    | 2                         | S1  | 50                 | 50                                    |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 50      | 25C   | BRA                                     |
| BC102    | 2                         | S1  | 100                | 100                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 100     | 25C   | BRA                                     |
| BC103    | 2                         | S1  | 200                | 200                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 200     | 25C   | BRA                                     |
| BC104    | 2                         | S1  | 300                | 300                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 300     | 25C   | BRA                                     |
| BC105    | 2                         | S1  | 400                | 400                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 400     | 25C   | BRA                                     |
| BC106    | 2                         | S1  | 500                | 500                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 500     | 25C   | BRA                                     |
| BC107    | 2                         | S1  | 600                | 600                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 600     | 25C   | BRA                                     |
| BC108    | 2                         | S1  | 700                | 700                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 700     | 25C   | BRA                                     |
| BC109    | 2                         | S1  | 800                | 800                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 800     | 25C   | BRA                                     |
| BC203    | 2                         | S1  | 200                | 200                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 200     | 25C   | BRA                                     |
| BC204    | 2                         | S1  | 300                | 300                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 300     | 25C   | BRA                                     |
| BC205    | 2                         | S1  | 400                | 400                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 400     | 25C   | BRA                                     |
| BC206    | 2                         | S1  | 500                | 500                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 500     | 25C   | BRA                                     |
| BC207    | 2                         | S1  | 600                | 600                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 600     | 25C   | BRA                                     |
| BC208    | 2                         | S1  | 700                | 700                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 700     | 25C   | BRA                                     |
| BC209    | 2                         | S1  | 800                | 800                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 800     | 25C   | BRA                                     |
| BC305    | 2                         | S1  | 400                | 400                                   |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 400     | 25C   | BRA                                     |
| BC307    | 2                         | S1  | 600                | 600                                   |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 600     | 25C   | BRA                                     |
| BC309    | 2                         | S1  | 800                | 800                                   |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 800     | 25C   | BRA                                     |
| BC1001   | 2                         | S1  | 900                | 900                                   |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 900     | 25C   | BRA                                     |
| BC1002   | 2                         | S1  | 1000               | 1000                                  |                                 |         | 1.0                                     | 25C         | 1.5                                       | 5.0                                 | 1000    | 25C   | BRA                                     |
| BC2001   | 2                         | S1  | 900                | 900                                   |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 900     | 25C   | BRA                                     |
| BC2002   | 2                         | S1  | 1000               | 1000                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 1000    | 25C   | BRA                                     |
| BC2003   | 2                         | S1  | 1100               | 1100                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 1100    | 25C   | BRA                                     |
| BC2004   | 2                         | S1  | 1200               | 1200                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 1200    | 25C   | BRA                                     |
| BC2007   | 2                         | S1  | 1500               | 1500                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 1500    | 25C   | BRA                                     |
| BC2010   | 2                         | S1  | 1800               | 1800                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 1800    | 25C   | BRA                                     |
| BC2012   | 2                         | S1  | 2000               | 2000                                  |                                 |         | .75                                     | 25C         | 2.8                                       | 5.0                                 | 2000    | 25C   | BRA                                     |
| BC3002   | 2                         | S1  | 1000               | 1000                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 1000    | 25C   | BRA                                     |
| BC3004   | 2                         | S1  | 1200               | 1200                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 1200    | 25C   | BRA                                     |
| BC3007   | 2                         | S1  | 1500               | 1500                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 1500    | 25C   | BRA                                     |
| BC3010   | 2                         | S1  | 1800               | 1800                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 1800    | 25C   | BRA                                     |
| BC3012   | 2                         | S1  | 2000               | 2000                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 2000    | 25C   | BRA                                     |
| BC3015   | 2                         | S1  | 2250               | 2250                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 2250    | 25C   | BRA                                     |
| BC3017   | 2                         | S1  | 2500               | 2500                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 2500    | 25C   | BRA                                     |
| BC3020   | 2                         | S1  | 2750               | 2750                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 2750    | 25C   | BRA                                     |
| BC3022   | 2                         | S1  | 3000               | 3000                                  |                                 |         | .50                                     | 25C         | 3.6                                       | 5.0                                 | 3000    | 25C   | BRA                                     |
| GA53691  | 1                         | S1  | 35                 |                                       | 10                              | 1.0     |   |             |   |                                     |         |       | WEC                                     |
| SD005    | 1                         | S1  | 50                 | 50                                    | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 50      | 100   | SSD                                     |
| SD010    | 1                         | S1  | 100                | 100                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 100     | 100   | SSD                                     |
| SD015    | 1                         | S1  | 150                | 150                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 150     | 100   | SSD                                     |
| SD020    | 1                         | S1  | 200                | 200                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 200     | 100   | SSD                                     |
| SD025    | 1                         | S1  | 250                | 250                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 250     | 100   | SSD                                     |
| SD030    | 1                         | S1  | 300                | 300                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 300     | 100   | SSD                                     |
| SD035    | 1                         | S1  | 350                | 350                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 350     | 100   | SSD                                     |
| SD040    | 1                         | S1  | 400                | 400                                   | 250                             | 1.0     | .25                                     | 25A         |   | 100                                 | 400     | 100   | SSD                                     |
| SD405    | 1                         | S1  | 50                 | 50                                    | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 50      | 150   | SSD                                     |
| SD410    | 1                         | S1  | 100                | 100                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 100     | 150   | SSD                                     |
| SD415    | 1                         | S1  | 150                | 150                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 150     | 150   | SSD                                     |
| SD420    | 1                         | S1  | 200                | 200                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 200     | 150   | SSD                                     |
| SD425    | 1                         | S1  | 250                | 250                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 250     | 150   | SSD                                     |
| SD430    | 1                         | S1  | 300                | 300                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 300     | 150   | SSD                                     |
| SD435    | 1                         | S1  | 350                | 350                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 350     | 150   | SSD                                     |
| SD440    | 1                         | S1  | 400                | 400                                   | 400                             | 1.5     | .40                                     | 25A         |   | 500                                 | 400     | 150   | SSD                                     |

## NOTATIONS

### Under Use

- General Purpose
- Power Rectifier
- Magnetic Amplifier

∅ Insulated Base

5. Controlled Rectifier

6. Dual Rectifier

△ Direct Tube Replacement

7. Controlled Forward Conductance

### Other

- For half wave resistive load average over 1 cycle

### Under Reverse Current

☑ Dynamic

### Under Mfr.

- Available in stock form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient

C — Case

J — Junction

S — Storage

△ — Inlet Temperature of Coolant

### Type No.

† — Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

### Under E<sub>r</sub>

☑ — at 125°C



# Market News . . .

## Prices

Philco has available a gallium arsenide mixer diode designed for 24 kmc. Type 1N3096R K-band diode is priced at \$75 each in quantities of 1-9 units. Matched pairs, type 1N3096m are priced at \$187.50 per pair. The firms Lansdale division has also reduced prices on both their Micro Alloy and Micro Alloy Diffused-Base transistors. Two units — the MAT 2N293 switch and the MADT 2N501 switching device — were cut to \$3.45 and \$4.90, respectively, in quantities of 1,000 or more. The 2N393 had cost \$4.15 each and the 2N501, \$6.75 each.

The other five MAT transistors, with old and new prices, include:

|             |        |        |
|-------------|--------|--------|
| 2N393 (Mil) | \$4.45 | \$3.75 |
| 2N1122      | 5.05   | 4.35   |
| 2N1122A     | 6.35   | 5.35   |
| 2N1411      | 4.30   | 3.40   |
| 2N1427      | 4.35   | 3.60   |

The other six transistors, all MADTs, with old and new prices, include:

|              |        |        |
|--------------|--------|--------|
| 2N499        | \$3.30 | \$2.65 |
| 2N499 (Mil)  | 3.50   | 2.80   |
| 2N501A (Mil) | 8.40   | 6.10   |
| 2N502        | 3.50   | 2.50   |
| 2N502A (Mil) | 4.40   | 3.10   |
| 2N504        | 2.90   | 2.30   |

Raytheon Co. has reduced prices on 24 silicon transistors. Switching transistors 2N333-38 and 2N1386-90 were reduced 18-58%. Subminiature types 2N745-51 were reduced 10-54%. Five of their power units were also reduced 18-32%.

Hughes Aircraft Company's semiconductor division has announced a price reduction of 10 to 55 per cent on its complete line of diodes, transistors and rectifiers. These include a reduction of 55 per cent on many of the division's silicon general purpose diodes, a 25 per cent drop in silicon mesa *p-n-p* high switching transistors, and similar reductions in germanium diodes, silicon rectifiers, silicon *p-n-p* fused junction transistors, silicon *p-n-p* high frequency transistors, and zener voltage regulator diodes.

Texas Instruments Incorporated has available four new gallium arsenide tunnel diodes. These are priced as follows:

|       | 1-99    | 100-999 |
|-------|---------|---------|
| 1N650 | \$27.30 | \$21    |
| 1N651 | 39.00   | 30      |
| 1N652 | 18.20   | 14      |
| 1N653 | 11.70   | 9       |

Sylvania has announced prices on three of its germanium tunnel diodes. Their D4115 with a minimum oscillation frequency of 2kmc, is listed at \$17.50 each; D4115 minimum of 3kmc, \$27.50 each; and D4115B minimum of 4kmc \$37.50 each.

Semiconductor division of Sarkes-Tarzan, Inc. has started supply production quantities of its line of silicon zener voltage regulators. Prices on 10% tolerance units for the 0.25w are from \$3.80 to \$5.55 each; for the 1w unit from \$3.95 to \$5.80 each and for the 10w unit from \$7.90 to \$8.60 each.

Minneapolis-Honeywell Regulator Co. has reduced prices up to 39% on seven of its H-5 line of germanium power transistors and 20% on four of its tetrode transistors.

Hoffman Electronics Corp. is now marketing solar cell assemblies. Type 2H5B which provides 32 ma is priced at \$16 each. Type H5C which provides 42ma is listed at \$22.40 each. The firm has also made available a new line of silicon controlled rectifiers. Encased in TO-5 transistor packages, the units consist of five *n-p-n-p* types. HCR-30N through HCR-200N and seven *p-n-p-n* types, HCR-30P through HCR 400P. Prices for the *n-p-n-p* devices depending on voltage types, range from \$8.40 to \$22.50 each in quantities of 1-99, and from \$5.60 to \$15 each in quantities from 100-999. The *p-n-p-n* units are priced from \$5.60 to \$60 each (1-99) and \$3.70 to \$40 each (100-999).

Electronic Chemicals Division of Merck and Co., Inc. has reduced prices on their electronic grade silicon from 6 to 28 per cent. Their new price list follows:

| FLOAT ZONE REFINED SINGLE CRYSTAL |             |            |  |
|-----------------------------------|-------------|------------|--|
| Type N                            | Type P      |            |  |
| Resistivity                       | Resistivity |            |  |
| Ranges                            | Ranges      |            |  |
| (Ohm Cm)                          | (Ohm Cm)    | Price/Gram |  |
| below 0.099                       | below 0.099 | *          |  |
| 0.1 to 1.0                        | 0.1 to 1.0  | 1.59       |  |
| 1 to 50                           | 1 to 100    | 1.39       |  |
| 51 to 100                         | 101 to 200  | 1.59       |  |
| 101 to 300                        | 201 to 300  | 1.79       |  |
| above 300                         | 301 to 1000 | *          |  |
|                                   | 1000 Min.   | 2.96       |  |

\* Prices in these ranges are quoted depending on specifications.

## POLYCRYSTALLINE SILICON

Polycrystalline Billets . . . 0.44/Gm  
High purity silicon with a maximum boron level of 1 part in 6 billion.

## Sales

According to the EIA, transistor manufacturers, during the first half of 1960, recorded a 67 per cent gain over 1959 in unit sales at the factory. June business increased over May by more than 1,300,000 transistors.

The following tables show EIA's monthly and year-to-date statistics:

|                  | Units      | Units        |
|------------------|------------|--------------|
| June             | 10,392,412 | \$27,341,733 |
| May              | 9,046,237  | 24,146,373   |
| April            | 9,891,236  | 23,198,576   |
| March            | 12,021,506 | 28,700,129   |
| February         | 9,527,662  | 24,831,570   |
| January          | 9,606,630  | 24,714,580   |
| Year-to-date '60 | 60,485,683 | 152,932,961  |
| Year-to-date '59 | 36,098,026 | 99,813,775   |

According to the U. S. Dept. of Commerce, Japanese output of electronic products in the first quarter of this year totaled \$281.1 million, up 53 per cent from the same period of 1959. Semiconductors registered the greatest percentage increase in production of any electronic product group for the first quarter 1960 compared with the first quarter 1959, up 67 per cent to \$19.1 million, closely followed by electron tubes, up 63 per cent to \$44.5 million. The output of radio receivers with three or more transistors in the first quarter of this year was valued at \$38.0 million, 95 per cent higher than in the first quarter of 1959.

## Financial

Philco has reported an increase in sales of 7.2% but a decrease in earnings of 19% for the first six months in 1960. First half sales were \$194,280,000 and earnings \$1,941,000 compared to sales of \$181,345,000 and earnings of \$2,386,000 for the same period last year. Earnings were 43¢ per common share compared to 54¢ last year. Transistor sales, however, more than doubled despite Defense Department cutbacks in the 2nd quarter.

Sperry Rand has reported a net profit for the quarter ending June 30 of \$5,410,579 equal to 19¢ per share. This is a decrease of almost 40% from the \$9,014,870 or 31¢ a share for the same period last year. Sales of products and services increased 6.2% to \$291,761,602 from \$274,694,309 from last year.

Texas Instruments Inc., has reported that profits for the first half of 1960 were up 26% over last year. Earnings were \$7,921,000 equal to \$2.00 per common share, as compared with \$6,305,000 or \$1.62 per share for the same period last year. Sales for the first six months were \$116,051,000 up from \$94,199,000 for the first half of 1959.

## Suppliers

Jupiter Electronics Inc., New York has introduced a 3-pin transistor holder using a spring-loaded collet locking mechanism. Designated as model T3T, it is priced at \$2.89 each and is available in 9 EIA colors.

High Purity Metals, Hacksensack, N. J. has developed an automated process for reclaiming high-grade germanium scrap. Their new process is being used to reclaim either on a toll basis or by supplying on a scrap-credit basis intrinsic polychrysaline line germanium.

Pellon Corp., New York has developed semiconductor polishing discs said to cut costs and polishing cycle time in the fabrication of microelectronic circuits and epitaxial crystals. The cloths are available in packages of one-dozen from 4½" to 12½" diameter with prices from \$3.50 to \$11 depending upon the style. These are being marketed by Geoscience Instruments Corp., N.Y.C.

Dow Corning Corp. is now marketing polycrystalline silicon in rod form at \$330 per pound under 100 pound lots. The rods are available in diameters up to 26mm and in lengths up to 17.7 inches. The firm is adding a 44,000 square foot addition to their two months old plant in Hemlock, Mich. The new addition is expected to be in operation by January 1961.

## Distributors

Standard Rectifier Corp. has appointed Hudson Radio & TV Corp., New York as an authorized industrial distributor.

Schweber Electronics, components distributor of Mineola, L. I., N. Y. has announced the relocation of its Eastern Sales Office. The new headquarters will be in the Perpetual Building, 8710 Georgia Avenue, Silver Spring, Maryland.

## New Firm

Tyco, Inc., is planning to locate in a Boston suburb. The new firm will initially produce existing products such as silicon transistors, silicon controlled rectifiers, tunnel diodes and other high frequency semiconductor devices.



# Industry News . . .

## CONFERENCE CALENDAR

### The Following November 1960 Meetings Are Scheduled:

- |            |   |                    |  |
|------------|---|--------------------|--|
| Nov. 4-5   | Communications Symposium, Queen Elizabeth Hotel, Montreal, Canada. Sponsored by Montreal Section IRE. For Information: C. F. Ripp, Box 802 Station B, Montreal, P.Q.                                | Nov. 14-17         | Conference on Magnetism & Magnetic Materials, New Yorker Hotel, New York City. Sponsored by AIEE, AIP, ONR, IRE, AIME, PGMT & T. For Information: A. M. Clogston & R. C. Fletcher, Bell Telephone Labs, Murray Hill, N. J. |
| Nov. 14-16 | Mid-American Electronics Conference (MAECON), Hotel Muehlebach, Kansas City, Mo. Sponsored by Kansas City Section IRE. For Information: J. E. Austin, Bendix Corp., 95th & Troost, Kansas City, Mo. | Nov. 15-17         | Northeast Electronic Research & Engineering Meeting (NEREM) Commonwealth Armory & Sheraton Plaza Hotel, Boston, Mass.  |
| Nov. 15-16 | PG on Production Tech. 4th Annual Conference, Boston Mass. Sponsored by PGPT & NEREM. For Information: C. W. Watt, Raytheon Co., Waltham 54, Mass.  | Nov. 27-28         | American Physical Society Meeting, Hotel Windermere, Chicago. Sponsored by AIP.  |
|            |   | Nov. 27-<br>Dec. 2 | ASME Annual Meeting, Statler & Sheraton-Atlantic Hotel, New York City.   |

## RESEARCH AND DEVELOPMENT

The semiconductor division of Hughes Aircraft Company is building a laboratory production line for a parametric mode transistor that operates at ultra-high and microwave frequency ranges in the circuit recently invented and demonstrated at Lenkurt Electric Co., Inc., a subsidiary of General Telephone & Electronics. The Hughes transistor was designed to operate in the parametric mode at a frequency range two to five times higher than what was considered the absolute frequency limit of any commercial transistor. It has produced nearly 4 kilomegacycles at 10 per cent efficiency when tested in the UHF and microwave mixer-oscillator circuit invented last fall by Dr. Vladimir W. Vodicka of Lenkurt's Advanced Development group. The transistor's designer, Hughes' physicist Rainier Zuleeg, predicts even higher frequency ranges in the microwave region — eventually up to 10 kilomegacycles while still retaining a minimum efficiency of 10 per cent.

Dr. Vodicka believes his discovery will lead to simplifying circuitry in communication equipment and possibly in electronic computers. Both emphasize that the circuit and transistor are still in developmental stages. "But even in this early stage," the scientists declare, "we are convinced these developments have unusually promising possibilities."

Studies underway at Bell Telephone Laboratories on one of the most efficient thermoelectric materials yet developed were discussed recently at the International Conference on Semiconductors at Prague, Czechoslovakia. The compound is composed of the elements silver, antimony, and tellurium. Its chemical designation is silver antimony telluride ( $\text{AgSbTe}_2$ ). The search for improved materials at Bell Laboratories centered on ternary intermetallic semiconductor compounds, many of which have a cubic crystal structure similar to sodium chloride. The desired crystal formation is somewhat disordered and contains heavy atoms such as tellurium. Many compounds, and alloys of compounds, some with as many as seven elements, have been produced and studied. The best of these discovered to date has been silver antimony telluride. This material is now being widely studied in labora-

tories in this country and around the world.

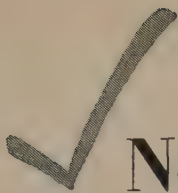
The material possesses a very low thermal conductivity, necessary in order to maintain a temperature differential between two ends of a device. Its thermoelectric figure of merit, "Z", has recently been measured by scientists at Radio Corporation of America, and is reported to be about  $1.75 \times 10^{-3}/^\circ\text{C}$  over a range of  $200^\circ$  to  $500^\circ\text{C}$ , which is the best yet observed for p-type thermoelements in this range. In the studies reported, silver antimony telluride was described as having a disordered cubic structure, exhibiting a thermal conductivity as low as  $0.0064 \text{ watts/cm}^\circ\text{C}$  at room temperature, only one one-hundredth that of germanium. While the material is always thermoelectrically p-type, its Hall effect is p-type in some specimens, and n-type in others, even when taken from a single ingot.



Drs. Raymond Wolfe (l.) and Jack H. Wernick, both of Bell Telephone Laboratories, check the mounting on a sample of silver antimony telluride before measuring its Hall coefficient. The sample was cut from a zone-refined crystal of the new thermoelectric material similar to the one in Dr. Wernick's hand.

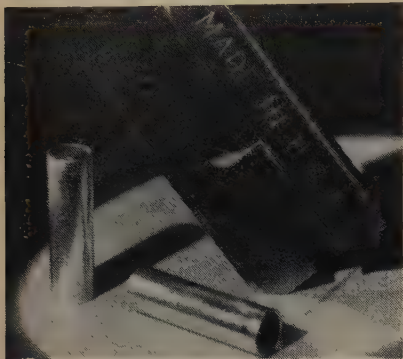
Aeroprojects Incorporated of West Chester, Pa., recently was granted two basic United States patents on ultrasonic welding; they contain method and equipment claims on both ultrasonic spot-type and ultrasonic seam welding.





## New Products

### Gallium Arsenide Mixer Diode



Philco Corporation's Lansdale Division has introduced a gallium arsenide microwave mixer diode. The new device is specified for 24,000 mc (k-band) first detector operation and is housed in a coaxial package identical to that used for existing silicon k-band diodes. It features a band-gap energy value of 1.48 electron volts and is capable of high temperature operation considerably in excess of the upper limit capabilities of germanium and silicon components. Higher mobility values achieved by the 1N3096R permit greatly increased sensitivity at 24 kMc. The diode exhibits an overall noise figure of 10.5 db. Changes in noise figure of less than 2 db have been noted for temperature ranges of 300° C.

Circle 111 on Reader Service Card

### KMC Oscilloscope

Type 519 is the new Tektronix KMC Oscilloscope—a calibrated, high-speed, laboratory instrument designed for observation, measurement, and photographic recording of wide-band phenomena. A 2 x 6 cm viewing area, coupled with 24 kv accelerating potential affords bright displays with excellent definition. Performance features include: passband from d-c to beyond 1000 mc, risetime of 0.35 nsec, sensitivity of 10 v/cm, linear sweeps to 2 nsec/cm, and sweep delay to 35 nsec. For clear display of: Recovery time of fast diodes, fast diode turn-on, avalanche transistors, tunnel diode wave forms, switching transistors, high-speed circuit analysis, etc.

Circle 116 on Reader Service Card

### Epoxy Tubing



Epoxy tubing for component encapsulation of capacitors, resistors, semiconductor devices, delay lines, coils, plug in components, etc., is available from Resdel Corp. Thirty-five sizes between .180" and 1.312" O.D.; larger sizes available. Supplied with any wall thickness, .015" and heavier. Produced in 57" lengths, precision cut to special lengths. Available in compounds and colors. Materials for high heat distortion, self extinguishing, low coefficient of expansion and other characteristics.

Circle 90 on Reader Service Card

### Mesa Transistor Series



A new germanium mesa transistor series for communications applications was announced recently by Texas Instruments Incorporated, featuring low noise figures with  $f$  (max) in excess of 1000 mc. 2N1405, 2N1406 and 2N1407 feature exceptional gain characteristics for transistors which operate in the VHF/UHF range. Each of these devices are production tested to assure maximum noise figures of 6db, 8db and 10db respectively at 200 mc. The series has excellent emitter-base diode characteristics which make them useful as mixers, well into the UHF range.

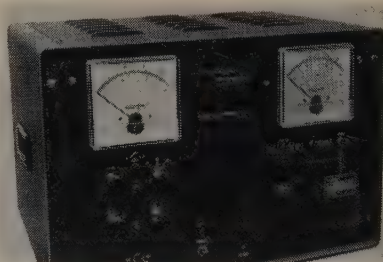
Circle 112 on Reader Service Card

### High Purity Silicon

High purity silicon in polycrystalline rod form is now being produced by Dow Corning. Above Grade I in quality, these rods are especially suitable for zone refining to the single crystal silicon used in power rectifiers, transistors, diodes, and other semiconductor devices. By vacuum zone refining, polycrystalline rod can be converted to single crystal silicon having typical resistivity greater than 1000 ohm-centimeter, minority carrier lifetime greater than 400 microseconds.

Circle 119 on Reader Service Card

### Test Set



Dynatran Model 1818 100 Megacycle & Gain Bandwidth Test Set provides direct readings of the 100 megacycle gain of transistors. It also provides direct readings of the gain bandwidth product up to 1000 megacycles. This instrument is complete in itself and requires no auxiliary equipment. It is power line operated and uses no batteries.

Circle 127 on Reader Service Card

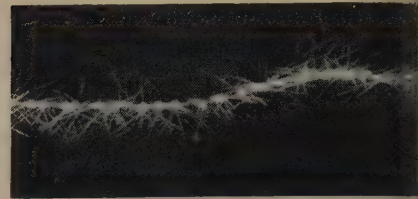
### Gold Alloy Preforms

Gold 99.99+ % pure alloyed with antimony, silicon, germanium, gallium or tin and fabricated into spheres, foil, washers, discs, rectangles and squares for semiconductor devices is now available from Alpha Metals, Inc. Dimensions of these materials are as follows: Spheres range from .005" with tolerances as close as .0001". Discs from .005" up. Foil from .0005" thin. Rectangles from .040" to .015". Squares .020". Washers from .020" i.d. and a land of .005".

Circle 121 on Reader Service Card

### Fuse Material

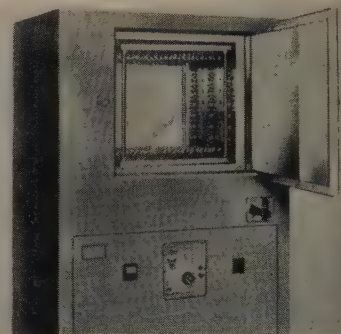
The manufacture of specially processed Pyroforic Products, now known as PYROFUZE, has been announced by Pyrofuze Corp., a newly-formed affiliate of Sigmund Cohn Corp. PYROFUZE material is available in the form of wire and ribbon, made in production quantities. The wire is a bimetallic product that disintegrates with explosive violence at 600° C without support of oxygen. It is recommended for explosively operated devices, electrically detonated. Also obtainable in experimental quantities as PYROFUZE sheet and stamped preforms.



Photograph taken a few milliseconds after ignition of 6" length of .003" diameter PYROFUZE Wire.

Circle 115 on Reader Service Card

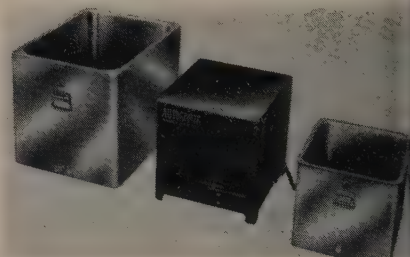
### Aging Ovens



Blue M mechanical convection, horizontal airflow aging ovens with saturable power reactor control and built-in range lock overtemperature protection are ideal for accelerated aging at controlled temperatures. Straight-line control derives from control system without contact switches, moving parts or auxiliary mechanisms to wear, burn or arc; there are no transient voltages due to arcing contacts. Temperature Range: 35°C. to 180°C. (356°F.)

Circle 129 on Reader Service Card

### 1000 Watt Ultrasonic Cleaner

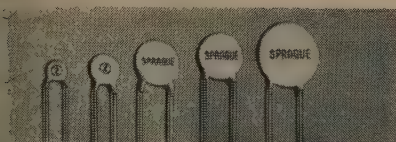


Industrial users of ultrasonic cleaning can maintain constant maximum efficiency in even the biggest cleaning operations with Powertron Ultrasonic Corporation's Autosonic Series 1000 ultrasonic cleaners. The new units require no operator attention or tuning, and maintain optimum cleaning performance by means of feedback transducer which electronically compensates for all varying load conditions. Multiple units may be combined in modular installations to give up to ten kilowatt operation.

Circle 134 on Reader Service Card



## Ceramic Disc Capacitors



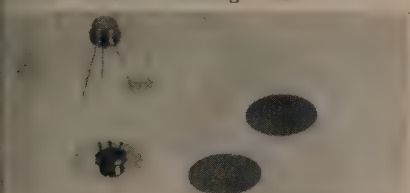
Designed to meet the small size, high capacitance demands of low voltage circuitry, Hypercon Ceramic Disc Capacitors offer capacitance values usually available only with electrolytic capacitors, yet these new units are only a fraction of the size of comparable electrolytic capacitors. They are the result of an extensive research program by the Sprague Electric Company to develop miniature ceramic capacitors especially suited for bypass and coupling applications in transistor circuitry. They have excellent stability with no loss in capacitance above room temperature. Operating Temperature Range:  $-55^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . Circle 113 on Reader Service Card

## Diffused Alloy Power Transistors

Bendix 2N1651, 2N1652 and 2N1653 is a series of Diffused Alloy Power DAP transistors designed for efficient high current switching at high frequencies. A diffused base region provides very low input resistance and high cutoff frequency (typical 2.0 Mc.) while maintaining high breakdown voltage ( $V_{ce}-120\text{ Vdc}$  absolute maximum rating for the 2N1653). The high frequency, high voltage characteristics are particularly suitable for use as a switch. In addition the flat beta parameter makes it ideally suited as an amplifier.

Circle 122 on Reader Service Card

## Semiconductor Polishing Cloth



A new polishing cloth has been developed by the Pellon Corporation and Geoscience Instruments, Inc. Especially suited for polishing semiconductor surfaces, it will produce the finishes required for fabricating mesa and planar devices, microelectronic circuits, epitaxial crystals and precision infrared optics. Adhesive backed Pellon Polishing Discs are available in a variety of sizes and are produced under ultra clean conditions to avoid contamination.

Circle 123 on Reader Service Card

## Silicon Mesa Transistor



Microbloc RT697M, a higher powered, improved 2N697 transistor in a new solid-state design, microminiature package, has been announced by Rheem Semiconductor Corporation. It has a guaranteed welded hermetic seal and occupies about 1/7th the volume of the standard 2N697, is .063 inches flat, .211 inches in diameter and weighs only 1/4 gram. Electrically, it not only meets all the specifications of the 2N697 but has 3 watts power dissipation, (50% more), resulting in cooler running junction for wider safety margins and higher reliability.

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# For SIMPLIFIED TRANSISTOR and DIODE TEMPERATURE MEASUREMENTS

## THE NEW RESCON TRANSISTOR THERMAL TEST SET

This single, self-contained unit provides complete facilities for temperature measurement problems in designing electronics equipment. It is especially applicable for determining transistor junction temperature measurements.

Determination of heat sink efficiencies, temperature rises, thermal environmental conditions, location of "hot spots", heat transfer efficiency of transistor mounts, and thermal gradients of the overall equipment are just a few of the unlimited applications.

The Thermal Test Set is easy to use — all readings are accurate and *direct* — no batteries, power compensations, calibrations or complex instructions required. Rugged construction for long-term service.



**RESCON**  
ELECTRONICS CORPORATION

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Circle No. 47 on Reader Service Card



# Modular Life Tester

The Wallson Model 154 Power Supply is used as a basic power supply in life testing semiconductor rectifiers. It incorporates the principles of simulator circuits, as opposed to brute force testing, i.e., a low voltage, high current transformer is used to supply forward current, and a high voltage, low current transformer is used to supply the reverse voltage.

- Operating Costs Reduced By a Factor of 50. The Model 154 will supply 32 amperes average rectified DC with inverse voltage from zero to 1000 volts peak. When operated at full capacity, over the course of a 1000 hour life test, the Model 154 can effect a savings of as much as \$242.24 at .01/Kw. hr. in operating cost.
  - Forward current and reverse voltage may be adjusted independently.
  - 100 Ma to 10 amp. forward current.
- Power can be brought out to the rectifiers under test through a variety of distribution panels which are designed to meet the user's requirements for metering and indication of failure.

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ASSOCIATES, INC.  
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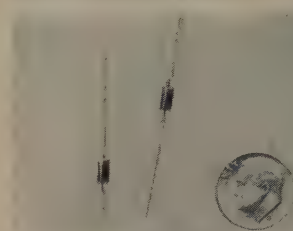
Circle No. 48 on Reader Service Card

## Industrial Laminates

A phenolic varnish producing a flame retardant, high electrical grade laminate with excellent cold punching properties has been announced by Monsanto Chemical Company's Plastics Division. Designated Resinox 495, the paper-based industrial laminates impregnated with the new phenolic varnish meet the electrical physical and mechanical requirements of NEMA standards and Underwriters' Laboratories test for flame resistance. They are especially recommended as copper-clad laminates for electronic computers and military applications.

Circle 128 on Reader Service Card

## Silicon Rectifier Diodes



A series of hermetically sealed silicon rectifier diodes, featuring high stability, extreme versatility, miniature design and rugged construction has been announced by Diodes, Inc. Designated DI-52, DI-54, DI-56, DI-58, and DI-51, these diodes have peak inverse voltage ratings of 200, 400, 600, 800, and 1,000 V respectively. All five types handle 750 ma at 25°C and 500 ma at 100°C. 100% output extends beyond 100 kc, with the 3-db point at 250 kc. Ambient temperature range is -65°C to +150°C.

Circle 124 on Reader Service Card

## High Purity Metals

The Research Chemicals Division of Nuclear Corporation of America has announced a new grade of rare earth metals representing higher purities. Designated (h.p.), they conform to the following specifications: Oxygen—less than 0.1%, Tantalum—less than 0.01%, Other rare earths—less than 0.1%, Iron—less than 0.03%. It is anticipated that these metals will prove of great interest for those in the electronics industry and associated industries where ever-increasing purities are of paramount importance.

Circle 126 on Reader Service Card

## Vacuum Pumping System

High Vacuum Equipment Corporation announces a new line of completely self-contained portable high-speed vacuum pumping carts or mobile evaporation units with 2-, 3-, 4- or 6-inch diffusion pumps. The completely packaged systems can be equipped with pumping port adapters for matching a wide range of vacuum furnaces, evaporation environmental chambers, or many other laboratory vacuum units and components.

Circle 93 on Reader Service Card

## Transistor Holder

A new 3-pin transistor holder, Model T3T, designed to eliminate holding fixtures of transistors undergoing shock, vibration and environmental tests has been introduced by Jupiter Electronics, Inc. Constructed of heat resistant materials, they have been used to hold transistors undergoing environmental tests to 260°C. Other applications include their use in equipment designed for the aging, reliability testing, and automatic checkout of transistors.

Circle 125 on Reader Service Card



#### Crystal Oscillators

A new line of precision transistorized crystal oscillators especially suited for application in communications systems, airborne electronic equipment, and guided missiles is available from the Industrial Systems division of Hughes Aircraft Company. They contain a silicon transistor oscillator circuit, and are in the frequency range of 1 mc to 5 mc, with a 10-hour frequency stability of  $\pm 2 \times 10^{-7}$ .  
Circle 120 on Reader Service Card

#### Centrifugation For Semiconductors



Reliability tests for diodes, transistors, capacitors and other semiconductors are now furthered by spinning them at high centrifugal speeds. Lourdes Instrument Corp. announces development of special centrifuge rotors with cavities cut to conform to exact contours of the components to be tested. Relative centrifugal forces from 10,000 to 25,000 times gravity are achieved, subjecting components to some of the effects encountered in space travel. The rotors can be designed to accommodate almost all semiconductor components.  
Circle 132 on Reader Service Card

#### Transistor Test Equipment

Herbert Industries is offering a line of transistor test equipment in modular form, designed for component testing by manual, semi-automatic, and automatic procedures. The test modules contain basic test circuits. Various read out panels containing standard or special indicators are available for use with the test modules. The equipment is fully unitized and compatible with present testing needs and future test equipment expansion programs.  
Circle 131 on Reader Service Card

#### Silicon Controlled Rectifiers

The Semiconductor Division of Hoffman Electronics Corporation recently announced the availability of a line of "complementary" silicon controlled rectifiers. The line consists of 5 *n-p-n-p* types which utilize negative gate current triggering; and 7 *p-n-p-n* types which are triggered by positive gate currents. All units are rated at 1 amp, average rectified forward current, and 1.4 amp, direct current, at plus 80° C. Operating and storage temperature range for all types is from -65° C to +150° C. Maximum junction temperature is +150° C.  
Circle 110 on Reader Service Card

#### New Slicing Method

A new method of slicing friable materials with the inside diameter of a donut-shaped cutting wheel has been introduced by The DoALL Company. The I/D Micro-slicer will cut scrap loss in half and yield many more wafers per ingot. Cutting wheels only .006- to .010-in. thick are used and kerf loss will be reduced 50 to 50% for semiconductor manufacturers, according to the company. The slicer is part of the company's new model MTA-70 slicing machine. This is one of four new Microtom-atic models designed for increased productivity.  
Circle 79 on Reader Service Card

(continued on page 62)

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Here is equipment that opens up entirely new fields for research—attaining Vacuum below  $1 \times 10^{-9}$  and making that Vacuum available for practical tests and studies with realistic pump down periods. Under favorable conditions Vacuum in the order of  $1 \times 10^{-10}$  mm Hg has been attained with this

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Special Research Grade  
**ANTIMONY**

TADANAC Brand Special Research Grade antimony is primarily developed for production of intermetallic compounds such as indium and aluminum antimonides. No individual impurity exceeds 0.1 ppm. and shipments can be made from sections of zone refined bars. These bars contain large crystals and have a very low oxygen content.

Other TADANAC Brand high purity metals or compounds include Special Research Grade indium and tin, High Purity Grade bismuth, cadmium, indium, lead, silver, tin, zinc, and indium antimonide. Send for our brochure on TADANAC Brand High Purity Metals.

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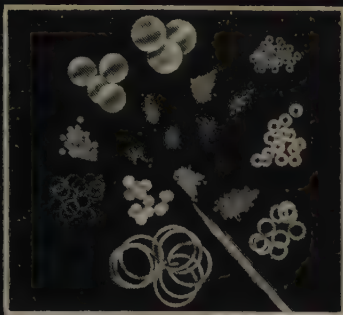
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All your requirements in a complete range of alloys for alloying and soldering, with purities held to 99.999+ % in the form of spheres, discs, washers, pellets and special shapes, precision fabricated to your specification.

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**Capable of Continuous Operation at  
temperatures to 1600 degrees C.**



for  
normal  
oxidizing  
atmosphere

Model  
FGKS-1296

## PERECO

### Kanthal Super Element FURNACE

Here's a general-purpose Pereco Furnace especially suited for areas of work calling for sustained high temperatures (up to 2900 degrees F) for long periods. Some of its features are: Kanthal Super elements; saturable reactor power control; graded, super-duty, lightweight insulation; and highest quality temperature controls. These are combined to provide extremely accurate temperature control, uniform heating, flexible cycling, cleanliness and economy of operating maintenance. Let us tell you how this unit—or other available size and type Pereco Kanthal units—might handle your work.

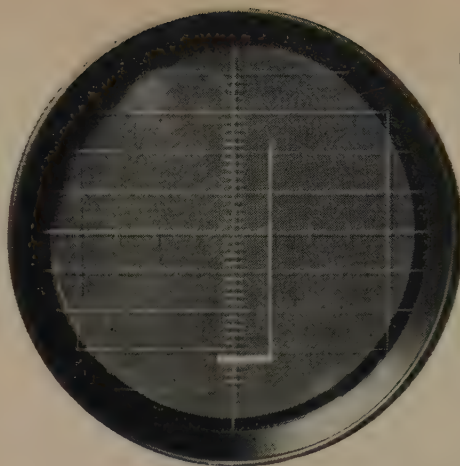
Standard and Special Furnaces for temperatures from 450 degrees to 5000 degrees F.

**PERENY EQUIPMENT CO., INC.**

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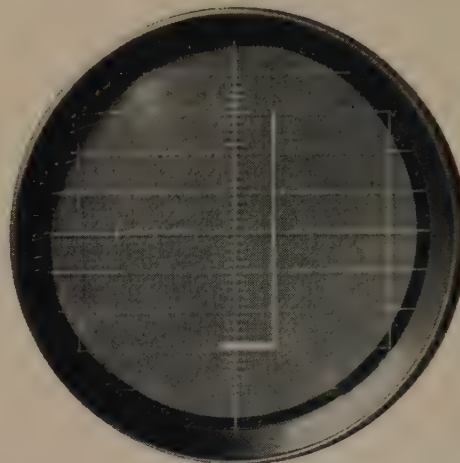
Columbus 12, Ohio

Circle No. 31 on Reader Service Card



**(before)**

Reverse leakage  
tracing before  
immersion  
in H<sub>2</sub>O<sub>2</sub>.



**(after)**

Reverse leakage  
tracing after  
immersion  
in H<sub>2</sub>O<sub>2</sub>,  
dried without  
washing  
(virtually no  
change).

**Here's proof !**

No increase in reverse leakage  
when you etch diodes in

**BECCO Hydrogen Peroxide!**



To test the effect of impurity-free Becco Hydrogen Peroxide across an unsealed diffused silicon junction diode, the following "tor-ture test" was performed: 600 volts AC were applied across the diode, and the reverse leakage current depicted on an oscillograph. Then, the diode was immersed in Becco 30% Reagent Grade Hydrogen Peroxide. The diode, without being washed in any way, was placed on a hot plate and the H<sub>2</sub>O<sub>2</sub> was evaporated.

The voltage was re-applied and the tracing produced was virtually identical (see above)—proof that no impurities that could affect the diode exist in Becco Hydrogen Peroxide.

Of course, you'll use Becco H<sub>2</sub>O<sub>2</sub> at a different stage—when you etch the diode. And, of course, good practice still dictates that you wash the diode in pure water following the etch. Nevertheless, this test proves that you need not be too concerned with your wash when you etch in Becco H<sub>2</sub>O<sub>2</sub>, since the peroxide itself, made by an inorganic method, can not deposit any impurities of its own on the diode.

Becco packages its Reagent Grade H<sub>2</sub>O<sub>2</sub> in returnable or non-returnable polyethylene containers to insure its purity when it arrives at your plant. Write us for further information or specifications, analysis, prices, etc. Address: Dept. SP-6.



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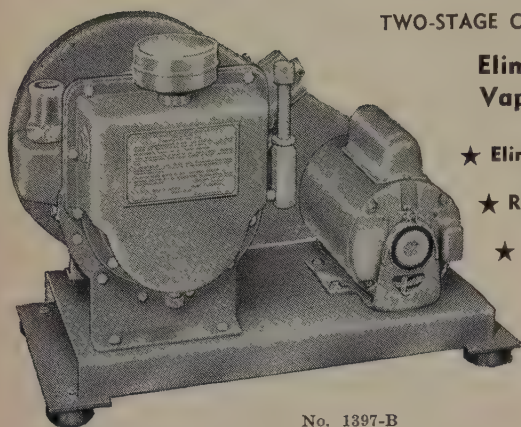
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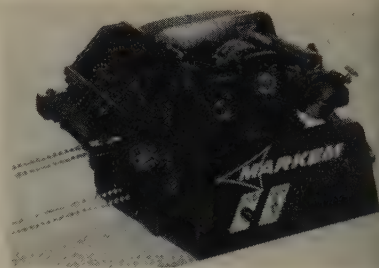
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# NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

## New Products (from page 59)

### Marking Machine



A new machine for marking axial lead components with text and polarity markings in accordance with JAN specifications has been announced by Marking Machine Company. At production speeds of 2,600 and more per hour, Model 146 prints trademark, polarity symbol and band, and desired code markings on diodes, capacitors, resistors and other axial lead components with curved or irregular surfaces. With optional features, this machine will also handle units with header leads. Visibility of imprints on crystal components can be increased by printing on a background color, using a combination of two Model 146A machines, one feeding automatically into the other.

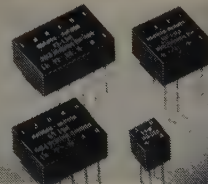
Circle 105 on Reader Service Card

### Audio Frequency Transistors

A series of general purpose p-n-p germanium alloy transistors which meet the mechanical and environmental requirements of MIL-S-19500B and associated specifications have been announced by Sylvania Electric Products Inc. The new hermetically sealed devices (Types 2N650, 2N651, and 2N652) are designed for both amplifier and switching applications in the audio frequency range. They have a maximum collector to base voltage of 45 volts, maximum collector to emitter of 25 volts, maximum collector current of 250 ma, and a maximum junction temperature of 100° C.

Circle 133 on Reader Service Card

### Digital Logic Elements



The Data Systems Division of Harnard-Kardon has introduced a line of Logic Elements representing a significant advance in digital building blocks. The following are some of the characteristics featured in these ruggedized packages: Operating temperature range of -65° C to +100° C; high density for car mounting applications; leads have 0.2" grid spacing; typical unit weighs 6 grams; fewer coupling circuits; no wasted component circuit simplicity; all units use 12 volt and/or +12 volt power supplies.

Circle 117 on Reader Service Card

### Switching Silicon Glass Diodes

A new series of high current silicon glass diodes was announced by Silicon Transistor Corp. Types 1N690 through 1N693, are capable of switching .5A current and are ideal for use in high current pulse circuits, diode logic circuits as well as for high speed computer switching pulse clamping, gating and blocking. Temperature range: -65°C to +150°C. Power dissipation 25°C: 400 mW max.

Circle 104 on Reader Service Card



### Transistorized Power Supply

Anders Electric Products Inc. Model 002A contains four regulated power supplies which are isolated and may be connected in many combinations for computers or transistorized equipment in the laboratory. Available voltages: 1 to 5 volts d-c for each output in current ranges of 2, 4, and 8 amperes. Regulation better than 0.1% for line and load. Ripple is better than 1 mv rms. Remote sensing and short circuit proof. Input range from 105 to 125 V, 50 to 400 cps, 1 phase. Operation up to 50°C ambient. Circle 100 on Reader Service Card

### Film-Forming Dielectric

Cyanocel, a new film-forming and moldable dielectric, a dielectric constant of 2.5, has been developed by American Cyanamid Company. Electroluminescence and microminiature capacitors are two known applications for this new material. Clear, transparent films as thin as 0.1 mil or as thick as 5 mils or more have been cast from solutions of highly cyanoethylated cellulose in a number of organic solvents or solvent mixtures. At a frequency of 60 cycles, the 2-mil films have a dielectric constant of 10-15 and a dissipation factor of 0.010-0.025. Circle 77 on Reader Service Card

### Silicon Diodes and Rectifiers

A new line of silicon diodes, rectifiers, power diodes and double anode diodes with a capacity of 500 mW and in a case measuring only  $\frac{3}{16}$ " diameter x  $\frac{1}{16}$ " thick has been announced by the Electronic Division of Controls Company of America. The new "Sildisc" diodes feature a double-cup design with maximum heat dissipation, and can be mounted in a variety of printed circuit applications permitting complete new assembly methods, according to company engineers. Circle 76 on Reader Service Card

### Static Contactors

A new line of Static Contactors is announced by Electronic Specialty Co. Relay Div. These devices are available in SPST, DPST, 3PST and 4PST models with output of 10 amperes at 115 VAC and input of 28 V @ 125 MA. Engineering designs are also available with output characteristics from dry circuit to 20 amperes a-c or d-c. Input values can be as low as 40 milliwatts. Temperature range from -54° C to -100° C. Utilization of silicon controlled rectifier circuitry permits performance of extremely high speed transfer functions while maintaining reliability in severe environments, shock, vibration and acceleration. Circle 130 on Reader Service Card

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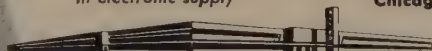
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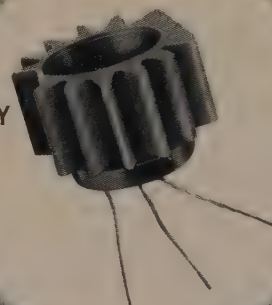
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## New Literature

Sigmund Cohn Corp. has issued a 4-page bulletin describing their B3 Exothermic Pyrofuze Wire which, when heated to about 650° C, ignites with explosive violence and reaches a temperature of about 2000° C. Illustrated in the folder is a photograph of the wire showing actual explosion taken 50 milliseconds after ignition. Duration of exposure was 2 milliseconds. Further descriptive information and characteristics of the material are given in the bulletin.

Circle 165 on Reader Service Card

CFI Corporation (Ceramics For Industry) has issued Bulletin 958 describing their line of custom ceramic parts for industry. The company specializes in the integrated design and production of precision ceramics in the form of components, ceramic-to-metal seals, glass-to-metal seals, specialized compositions. Bulletin gives technical details on these and other products, as well as description of available services.

Circle 166 on Reader Service Card

Infrared Bulletin 11-010, a new 8-page brochure available from Barnes Engineering Company gives a comprehensive outline of the historical development and the scientific principles of 'black body' infrared radiators. It covers fundamental theory, the various radiation laws, and the curves and equations evolved by the major classical scientific contributors to the field. The bulletin includes a discussion of present-day design considerations for laboratory standard sources, as applied in Barnes OptiTherm (trademark) instruments, and detailed descriptions, photos and specifications are given for their complete line of infrared sources.

Circle 167 on Reader Service Card

Technical Bulletin #A-309, listing and describing standard Type A dessicant dryers is available upon request from Trinity Equipment Corporation. The bulletin lists sizing information, as well as operational and mechanical specifications on the wide range of Type A dryers available from the company.

Circle 168 on Reader Service Card

Allied Radio Corporation announces the release of its 1961 catalog of electronic equipment. Special emphasis has been placed on electronic equipment for industry. The new 576-page catalog lists over 48,000 items and includes 240 pages in rotogravure. It includes extensive listings of parts and equipment for industrial maintenance, research, and production requirements.

Circle 170 on Reader Service Card

Weldmatic Division Unitek Corp. has published the first issue of its new 8-page magazine; **ELECTRONIC WELDING**. Issued quarterly, it will provide the electrical, electronic and metal-working industries with authoritative, up-to-date information on precision metal-joining applications, such as assembly of electronic packaging, fine wire leads, thin and hard foils and screens, and miniature circuit modules.

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knowing  
how

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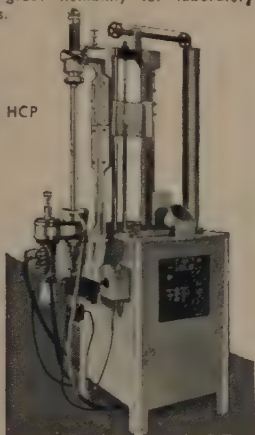


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Circle No. 38 on Reader Service Card

A new 32 page Safety Enclosure Catalog has been released by the Kewaunee Scientific Equipment Division of Kewaunee Manufacturing Company. It illustrates and describes their line of glove, vacuum and dry boxes; and controlled atmosphere systems for research and production purposes. Several pages are also devoted to illustrations of special enclosures and equipment made to a particular customer's requirement.

Circle 172 on Reader Service Card

Monsanto Chemical Company's Plastics Division has published a revised edition of a booklet describing the properties and typical end uses of its diversified line of plastic materials. The 12-page booklet includes detailed results of ASTM tests on the company's broad range of Lustrex styrene, Polyethylene and Opalon vinyl chloride molding compounds. It also features general information about the forms, typical uses and characteristics of Monsanto's fabricating, extruding, calendaring and laminating materials; industrial, textile, surface and paper coating resins; adhesives and intermediates.

Circle 173 on Reader Service Card

Norton Company's new bulletin entitled "Mounting Sensing Elements" describes methods of mounting temperature and strain measuring elements by means of ROKIDE ceramic spray coatings. This technique is being used to mount such elements in areas subject to high temperatures, such as rocket nozzles, gas turbines, and nose cones, particularly in testing operations.

Circle 174 on Reader Service Card

"How to Clean Ultrasonically with Self Tuning," a bulletin prepared by Powertron Ultrasonics Corporation engineers, provides a basic explanation of how ultrasonics works, what it can do to provide the safest and most consistent cleaning performance, and a guide to selecting the correct tank and generator sizes or console model for the user's needs. A thorough chart-guide to the correct cleaning solutions and temperatures for more than 20 different common contaminants completes the bulletin, designated 60-1.

Circle 175 on Reader Service Card

Two transistor test instruments are described in a new 4-page brochure issued by The Hickok Electrical Instrument Company. Three pages are devoted to the new Model 870 Dynamic Beta Transistor Tester; complete specifications are given along with schematic diagrams showing the methods employed to measure a-c and d-c beta with the instrument. The fourth page describes Model 850P Portable Transistor Analyzer, with suggestions concerning its use as a breadboard in transistor research.

Circle 176 on Reader Service Card

A new Bulletin Sheet describing Penfield's latest Model M-100 Mono-Column Demineralizer has just been published. The unit supplies up to 120 GPH of ultra high purity water with ion exchange action of top efficiency assured by a special control system that automatically keeps incoming flow constant. Complete specifications are given.

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**Accurate Specialties Company, Inc.** . . . . . 61  
**Aeroprojects Incorporated**  
**Aerotronic Associates, Incorporated**  
**Ajusto Equipment Company**  
**Allegheny Electronic Chemical Company** . . . . . 18  
**Allied Chemical Corporation**  
**General Chemical Division** . . . . 3  
**Allied Radio Corporation** . . . . . 63  
**Alloys Unlimited Incorporated** 10, 11  
**Alpha Metals, Incorporated** . . . . 12  
**American Optical Company**  
**Art Wire Stamping Company**  
**Avnet Corporation** . . . . . 67

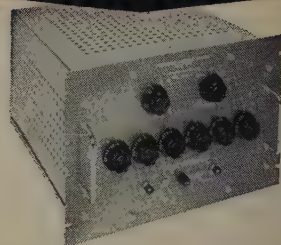
**BTU Engineering Corporation**  
**Baker, J. T. Chemical Company** 64  
**Becco Chemical Division**  
**Food & Machinery & Chemical Corp.** . . . . . 61  
**Bendix Corporation, The**  
**Red Bank Division**  
**Birtcher Corporation, The** . . . . . 63  
**Blue M Electric Company**  
**Boonton Electronics Corporation**  
**Brinkman Instruments, Inc.**  
**Bronwill Division of Will Corporation**  
**Burke & James, Incorporated**

**CBS Electronics**  
**Cambridge Communications Corporation**  
**Ceramics For Industry, Corporation**  
**Charleston Rubber Company**  
**C. P. Clare Transistor Corporation** . . . . . 33, 34, 35, 36  
**Cohn, Sigmund Corporation**  
**Columbus Electronics Corp.**  
**Conforming Matrix Corporation**  
**Consolidated Mining & Smelting Company of Canada** . . . . . 60  
**Consolidated Reactive Metals, Inc.**  
**Consultants Bureau Enterprises**  
**Custom Scientific Instruments, Incorporated**

**Davison Chemical Company**  
**Division of WR Grace**  
**DI-Tran Corporation**  
**DoAll Company, The**  
**Dow Corning Corporation**  
**Duramic Products, Incorporated** 60  
**Dynatran Electronics Corporation**

**Eagle-Picher Company, The**  
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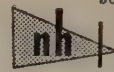
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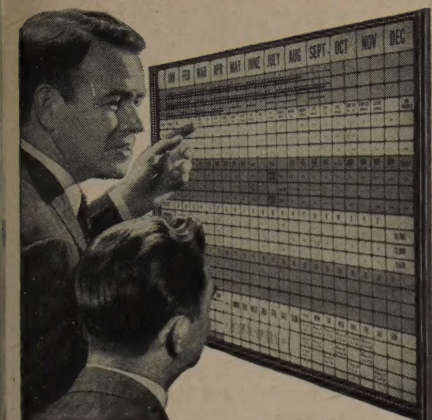


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General Instruments Incorporated  
Glass Beads Corporation  
Grace Electronic Chemicals Inc. 1  
Graphic Systems . . . . . 67  
Greibach Instruments  
Corporation

Hayes, C. I., Incorporated . . . . . 66  
Hevi-Duty Electric Company . . . 17  
Hickok Electrical Instrument  
Company, The  
Hoffman Electronics Corporation  
Semiconductor Division Cover II  
Hughes Aircraft Company  
Hunter Tools Company

Indium Corporation of  
America, The  
Industro Transistor Corporation  
Instant Circuits  
Institute of Radio Engineers  
International Business Machines

JFD Manufacturing Company,  
Inc. . . . . 14  
Johnson & Hoffman Manufactur-  
ing Company . . . . . 60

Kahle Engineering Company . . . 20  
Kanthal Corporation, The  
Kessler, Frank Company, Inc.  
Kewaunee Scientific Equipment  
Knapic Electro-Physics  
Incorporated . . . . . Cover III  
Kulicke & Soffa Manufacturing  
Company, The

L & R Manufacturing Company  
Labline, Incorporated . . . . . 68  
Lafayette Radio . . . . . 68  
Lepel High Frequency  
Laboratories . . . . . 65

Lindberg Engineering Company  
McCall, Tom & Associates, Inc.  
Manufacturers Engineering &  
Equipment Corporation  
Marshall Products Company  
Measurements Research  
Company  
Merck & Company, Incorporated  
Electronic Chemicals Division . 5  
Micromech Manufacturing  
Corporation . . . . . 13  
Milgray . . . . . Covers IIA, IIB  
Minneapolis-Honeywell  
Division  
Monsanto Chemical Company  
Mueller Electric Company

National Findings  
Newark Electronics Corporation  
New York Air Brake Co., The  
Kinney Manufacturing Division 59  
North American Electronics, Inc.  
North Hills Electronics, Inc. . . . 66  
Norton Company

(Continued on Pg. 68)

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## INDEX TO ADVERTISERS

(Continued)

- Ohio Carbon
- Penfield Manufacturing Company, Inc.
- Pereny Equipment Company ... 61
- Pitt Precision Products, Incorporated
- Powertron Ultrasonics Corporation
- Pure Carbon Company, Inc. ....
- Radio Receptor Co., Inc.
- General Instrument Corp.
- Raytheon Company
- Commercial Apparatus & Systems Division, Test & Productions Tools
- Semiconductor Division
- Rescon Electronics Corp. .... 57
- Research Chemical Division
- Nuclear Corp. of America
- Rheem Semiconductor Corporation ..... 6, 7
- Sandland Tool & Machine Company
- Schweber Electronics ..... 2
- Secon Metal Company ..... 63
- Semi-Alloys, Incorporated
- Semimetals, Incorporated ..... 13
- Shielding, Incorporated
- Sonex, Incorporated ..... 67
- Sprague Electric Company Cover IV
- Sperry Rand Corporation
- Standard Rectifier Corporation
- Sylvania Electric Products, Incorporated
- Chemical & Metallurgical Division
- Parts Division ..... 8
- Semiconductor Division
- Tang Industries ..... 64
- Tektronix, Incorporated ..... 19
- Texas Instruments Incorporated
- Geosciences & Instrumentation Div. .... 16
- Metals & Controls Div.
- Semiconductor-Components Div.
- Trak Electronics Co. Div. of CGS Labs. .... 66
- Transitron Electronic Corporation
- Trinity Equipment Corporation
- Ultrasonic Industries
- UNiform Electronics
- United Carbon Products, Company ..... 22
- United Components Incorporated
- United States Dynamics, Inc. .... 62
- United States Transistor Corporation
- Unitron Instruments Division of United Scientific Company
- Veeco Vacuum Corporation
- Wallson Associates, Incorporated 58
- W. M. Welch Manufacturing Company ..... 62
- Weldmatic Division
- Unitek Corporation
- West Instrument Corporation



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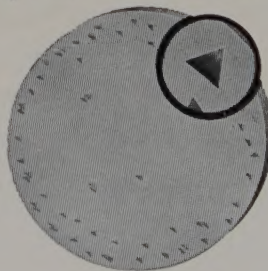
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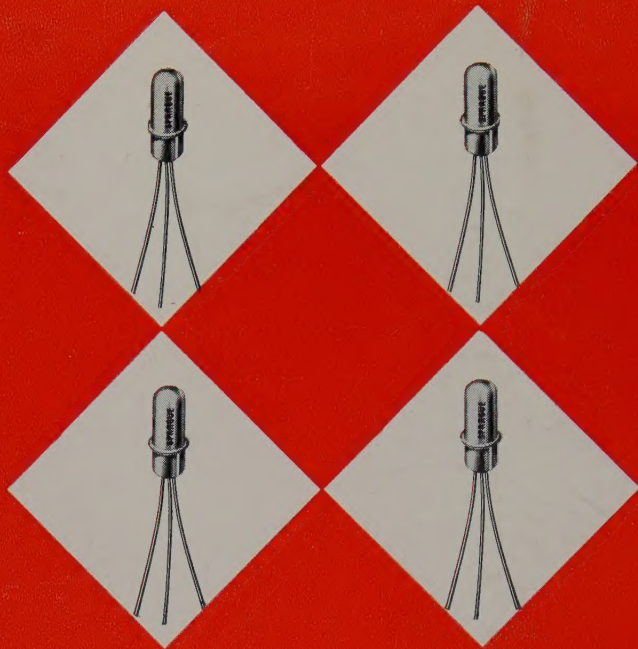
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